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TECHNICAL MEMORANDUM

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ORBITAL ANALYST HANDBOOK

4 May 1964

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APPROVED

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5-27 thru 5-64	A (1 July 1964) New pages
"GLOSSARY" tab	A (1 July 1964) New tab

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Section 1

INTRODUCTION

This handbook has been prepared to provide ~~1st Aerospace~~ Control ~~Squadron~~ (ADC) personnel assigned to the Orbital Analyst position in SPACETRACK with detailed procedures and standardized methods for accomplishing their assigned tasks in satellite processing. These tasks are:

a. Domestic Launch

b. Foreign Launch

c. Debris Separation

d. Proximity Determination

e. Element Maintenance

f. Decay Prediction

Each task represents a major orbital problem. A check list for each problem is provided. The required steps leading to the solution of the problem are identified. Analyst procedures are described and cross-referenced to pertinent tasks. Computer programs which support the orbital analyst are organized by functional area and detailed with respect to their use, input options and formats, and output format. Other system programs not of primary interest to the analyst are identified and briefly discussed. Standard system card formats, the system tape requirements, and the operating modes are described in detail. Aids, charts, graphs, and other material which assist in job performance are to be found in the appendix.

Section 2

TASKS

The analyst is responsible for solving a variety of orbital problems. These may occur independently or in numerous combinations. There are six such problems, each constituting a task. Each task is described at two levels of detail. The Check List identifies the major requirements of the task, and the task description identifies a workable set of procedures which will suffice for task accomplishment in a majority of cases. Each of the procedures is referenced to a more detailed description of its use in the Procedures section of this document.

The following tasks are described:

2.1 DOMESTIC LAUNCH

2.1.1 Check List

2.1.1.1 Satellite classification

2.1.1.2 Pre-launch information

2.1.1.3 Pre-launch folder:

a. 1ACS Form 31
b. Calculated element set
c. Computed element set
d. Nominal bulletin
e. Nominal look angles
f. Launch memo
g. Launch messages

2.1.1.4 Lift-off time

2.1.1.5 Sensor notification

2.1.1.6 Adjusted element set (Ω_o, T_o)

2.1.1.7 Sensor notification

2.1.1.8 SPADATS object number

2.1.1.9 International code name

2.1.1.10 Released bulletin and look angles

2.1.2 Task Description

2.1.2.1 Determine security classification of satellite.

2.1.2.2 Gather the following pre-launch information and initiate Form 31, to include:

a. Nominal number

b. Day of Launch

c. P_A = anomalistic Period (in days), or

d. a = semi-major axis

e. i = inclination

f. e = eccentricity

g. ϕ_i = injection latitude

h. λ_{w_i} = injection longitude

i. Time from lift-off to injection

j. Direction of satellite motion at I: northerly or southerly

2.1.2.3 Manually calculate a nominal element set (procedure 3.1), as follows:

a. Calculate ω_o:

$$\sin u = \frac{\sin^o |\phi_i|}{\sin i}, \text{ (N.)}; \quad \sin(180^o - u) = \frac{\sin |\phi_i|}{\sin i}, \text{ (S.)}$$

$$\omega_o = u, \ (\phi_i \text{ is } +); \quad \omega_o = 360^o - u, \ (\phi_i \text{ is } -).$$

b. Calculate T_O:

$$\operatorname{Tan} \frac{E}{2} = \left[\sqrt{\frac{1-e}{1+e}}\right] \operatorname{Tan}\left[\frac{\omega_o}{2}\right]; \text{ if } 0^o \le \frac{\omega_o}{2} \le 90^o, \text{ then } 0^o \le \frac{E}{2} \le 90^o$$

$$\cot\left[\frac{E - 180^o}{2}\right] = \left[\sqrt{\frac{1-e}{1+e}}\right] \cot\left[\frac{\omega_o - 180^o}{2}\right]; \text{ if } 90^o < \frac{\omega_o}{2} \le 180^o,$$

$$\text{then } 90^o < \frac{E}{2} \le 180^o$$

$$M^o = E - \left[(e \sin E)(57.3)\right]$$

$$\Delta t = \frac{MP_A}{360^o}$$

T_i = Time of lift-off (in days) + Time from lift-off to injection (in days).

$T_O = T_i$ (in days) - Δt

NOTE: Nominal time of lift-off is assumed to occur at 0000Z hours on the day of launch.

c. Calculate Ω_O (with $\theta_{o(1964)} = 98.74077$):

$$\theta_{G_{T_O}} = \theta_o \left[(T_o \times 1.00273791) \ (360^\circ)\right] ;$$

$$\overline{ER} = \Delta t \times 360^\circ,$$

$$\cos \Delta\lambda = \frac{\cos u}{\cos \phi_i},\ u \leq 90^\circ;\ \cos (180^\circ - \Delta\lambda) = \frac{\cos (180^\circ - u)}{\cos \phi_i},\ 90^\circ < u \leq 180^\circ$$

$$\lambda_{W_o} = \lambda_{W_i} \pm \Delta\lambda - \overline{ER}$$

$$\Omega = \theta_{G_{T_O}} - \lambda_{W_o}$$

d. Determine C from eccentricity vs. perigee plot (Fig. 2-1); where perigee height (q) (in earth radii) = a (1-e).

2.1.2.4 Compute a nominal element set (procedure 3.1) using the 1620 launch program.

2.1.2.5 Compare the nominal element sets and make the necessary corrections on the seven-card element set cards output by the 1620 program.

2.1.2.6 Build a special SEAIC tape for the launch (procedure 313) using the SEAI program.

2.1.2.7 Generate a bulletin (procedure 3.7) and look angles (procedure 3.8) using the BLTNSGP and GLASGP programs (OCS 17). The security classification of the look angles is the higher of the classification of the sensor or the satellite. The security classification of the bulletin is the same as that of the satellite. Insure appropriate sensor tasking.

2.1.2.8 Examine the bulletin and look angles for errors and release through the Project/Sensor Branch.

2.1.2.9 Receive actual lift-off time.

2.1.2.10 Notify the sensors by phone of the time of their first pass, immediately after lift-off and just prior to acquisition.

2.1.2.11 Calculate T_0 and Ω_0, as follows:

a. Calculate T_0: Increase nominal T_0 by lift-off time (in days).

b. Calculate Ω_0: Re-calculate Ω_0 using T_0.

2.1.2.12 Update the nominal element set to reflect actual Ω_0 and T_0.

2.1.2.13 Correct the nominal element set using reported observations.

2.1.2.13.1 If the initial observations are identified with the satellite, and if they sufficiently represent the orbit of the satellite, correct the nominal element set (procedure 3.5) using the SGPDC program. This is usually done after two or three revolutions of data have been received.

2.1.2.13.2 If insufficient tagged observations are received:

a. From BMEWS sensors = separate all observations on the 410 tape within the expected sensor acquisition times from the balance, using the MAP, ORCON and OBSSEP programs; associate the observation on the high-priority R-tape with all element sets in the E-file (procedure 3.4), using the RASSN program; generate observation cards, using the SRTMRG program; retrieve all unassociated observation cards manually.

b. From other sensors - retrieve all possibly associated observation cards.

c. Associate the observations (procedure 3.4) with the nominal element set, using the RASSN program in the SCHTP mode with lenient association parameters.

d. Correct the nominal element set (procedure 3.5), using the associated observations only, in the SGPDC program.

e. If the DC fails, compute an initial element set (procedure 3.2) using IOHG, etc., or manually adjust the nominal elements (procedure 3.9) as warranted;

f. Correct the element set again (procedure 3.5) using the SGPDC program.

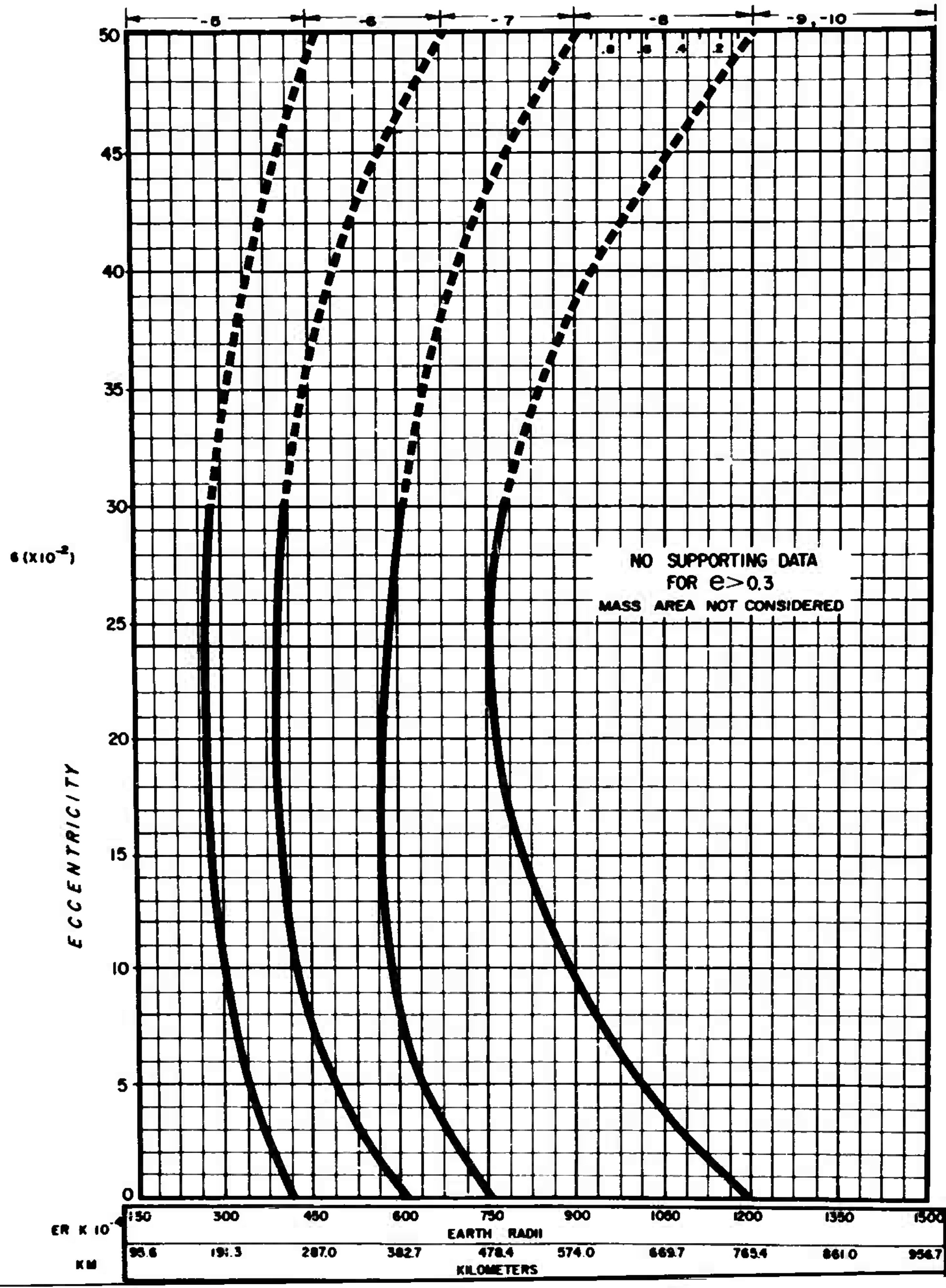
2.1.2.14 If the DC is successful:

a. Change the initial and final revolution on the seventh card of the element set.

b. Update the E, A and I files on the SEAIC tape (procedure 3.3) using the SEAI program.

c. Publish a bulletin (procedure 3.7) and look angles (procedure 3.8).

C TERM


-5
-6
-7
-8
-9, -10
.8
.6
.4
.2
NO SUPPORTING DATA
FOR e>0.3
MASS AREA NOT CONSIDERED
e (X10^-2)
ECCENTRICITY
ER X 10^-4
EARTH RADII
KM
KILOMETERS
150 300 450 600 750 900 1050 1200 1350 1500
95.6 191.3 287.0 382.7 478.4 574.0 669.7 765.4 861.0 956.7

2.2 FOREIGN LAUNCH PROCESSING

2.2.1 Check List

2.2.1.1 Discrimination

2.2.1.2 Observation selection

2.2.1.3 Element set determination

2.2.1.4 Nominal element set adjustment (T_0 and Ω_0)

2.2.1.5 Initial element set evaluation

2.2.1.6 Element set correction

2.2.1.7 Nominal element set evaluation

2.2.1.8 SEAIC update

2.2.1.9 Trial bulletin

2.2.1.10 Sensor tasking

2.2.1.11 Released bulletin and look angles

2.2.2 Task Description

2.2.2.1 Compare initial fan data with Beam Projection charts for discrimination purposes.

2.2.2.2 Examine initial observations for a major trend (procedure 3.4 and 3.10) and remove those observations which deviate from such a trend. Retain the deviate observations for use in determining the possible existence of debris.

2.2.2.3 If the initial observations are fan data, compare them with the RADINT charts.

2.2.2.4 Determine from the RADINT charts comparison if any of the nominal element sets can be used to represent the initial fan data (procedure 3.1).

2.2.2.5 If one of the nominal element sets represents the initial fan data, update T_0 and Ω_0 based on assumed lift-off time (see appropriate folder).

2.2.2.6 If none of the nominal element sets represents the initial fan data, manually calculate an element set using the initial fan data and selected information (procedure 3.1).

2.2.2.7 If the initial observations are tracker data, compute an initial element set (procedure 3.2) using the IOHG program.

2.2.2.8 If the initial observations are telemetry data, compute an initial element set (procedure 3.2) using the IOANGLE program.

2.2.2.9 If the initial observations are geocentric rectangular coordinates and velocity data, compute an initial element set (procedure 3.2) using the ROC program.

2.2.2.10 If the initial observations are simply two or more isolated radar fixes, from the same or different stations and/or on the same or different revolutions, compute an initial element set (procedure 3.2) using the IORF program.

2.2.2.11 Correct the nominal element set (procedure 3.5) using the initial fan data in the SGPDC program.

2.2.2.12 Evaluate the element set for acceptability by examining the residuals and elements for reasonable values in:

a. Δ t

b. Δ t range

c. $\Delta\beta$

d. $\Delta\beta$ range

e. Perigee height

f. Period

g. Drag

2.2.2.13 If any of the elements is unacceptable, correct the element set (procedure 3.5), using additional observations in the SGPDC program.

2.2.2.14 If the DC fails, treat the satellite as an element maintenance problem.

2.2.2.15 If the DC is successful, evaluate the element set for acceptability.

2.2.2.16 When all the elements are acceptable, add the element set to the System SEAIC files and the SEAIC tape (procedure 3.3) using the Special SEAIC program. A bulletin (procedure 3.7) and look angles (procedure 3.5) will be generated automatically, as well as a trial bulletin.

2.2.2.17 Examine the trial bulletin for acceptability.

2.2.2.18 Insure appropriate sensor tasking (procedure 3.6).

2.2.2.19 Release the bulletin and look angles through the DSSO.

2.3 DEBRIS SEPARATION

2.3.1 Check List

2.3.1.1 Corrected main element set

2.3.1.2 Selected debris observations

2.3.1.3 Debris element set(s)

2.3.1.4 SEAIC update

2.3.1.5 Sensor tasking

2.3.1.6 Released bulletin and look angles

2.3.2 Task Description

2.3.2.1 Correct the main element set (procedure 3.5) using the most recent observations in the SGPDC program.

2.3.2.2 Select from all associated observations (procedure 3.10) those which may represent debris pieces rather than the main body.

2.3.2.3 Associate the debris observations with the main element set (procedure 3.4), using the REDUCT program or the RASSN program in the SCHTP mode.

2.3.2.4 Examine the residuals to identify groups of observations which may constitute major trends related to debris objects (procedure 3.10).

2.3.2.5 Modify the main element set (procedure 3.5) (with a temporary identification number), using each group of selected debris observations in the SGPDC program, producing a debris element set for each debris object.

2.3.2.6 If the DC fails, modify the main element set (procedure 3.5) using the time residuals of the debris observations in the SYSBULL program, producing a debris element set.

2.3.2.7 Change the temporary identification number to the next usable satellite number, assign the proper International Code suffix, and add the debris element set and appropriate acquisition and information data to the System SEAIC files and the SEAIC tape (procedure 3.3) using the SEAI program.

2.3.2.8 Insure appropriate sensor tasking (procedure 3.6).

2.3.2.9 Generate a bulletin and look angles.

2.3.2.9.1 If the debris is from a foreign satellite, generate a bulletin (procedure 3.7) and look angles (procedure 3.8) using the BLTNSGP and GLASGP programs (OCS 17), and release as soon as possible, insuring appropriate security classification.

2.3.2.9.2 If the debris is from a domestic satellite, generate look angles (procedure 3.8) using the GLASGP program (OCS 19), and release as soon as possible, insuring appropriate security classification. A bulletin is usually not required on domestic debris.

2.4 PROXIMITY DETERMINATION

2.4.1 Check List - for orbits related to each other

2.4.1.1 Observation association

2.4.1.2 Element set correction

2.4.1.3 Initial proximity computation

2.4.1.4 Final proximity computation

2.4.1.5 Proximity determination

2.4.2 Check List - for orbits related to a given point and time

2.4.2.1 Initial proximity computation

2.4.2.2 Element set correction

2.4.2.3 Final proximity computation

2.4.2.4 Proximity determination

2.4.3 <u>Task Description</u> - for orbits related to each other.

2.4.3.1 Associate all observations (procedure 3.4) with one element set using the RASSN program in the SCHTP mode.

2.4.3.2 Examine all residuals to identify groups of observations (procedure 3.10) which may constitute major trends related to different orbits.

2.4.3.3 Determine an element set for each orbit (procedures 3.2 or 3.5)

2.4.3.4 Correct each element set (procedure 3.5) with epoch time being the time of nodal crossing for the revolution on which closest estimated proximity occurred.

2.4.3.5 Compute the time, distance and positions of closest proximity using the XROADS program, with the time range equal to the span of time during which closest estimated proximity occurred.

2.4.3.6 Examine the XROADS program output for the smallest proximity distance.

2.4.3.7 Recompute the time, distance and positions of closest proximity using the points of smallest proximity distance in the XROADS program and as small a time range as is reasonable and meaningful. This may be repeated until the analyst achieves the desired level of estimation accuracy.

2.4.3.8 Determine from the final XROADS output the point, time and distance of closest proximity.

2.4.4 <u>Task Description</u> - for orbits related to a given point and time.

2.4.4.1 Compute all satellite positions relative to a given time and generate a Position Situation Report using the PSR program.

2.4.4.2 Examine the Position Situation Report to determine those satellites within the required range of the given point.

2.4.4.3 Correct each element set (procedure 3.5) using the SGPDC program in the SCHTP mode.

2.4.4.4 Recompute each satellite position for the revolution on which the satellite is closest to the given point and time using the GRNTRK program.

2.4.4.5 Determine from the output of the GRNTRK program those satellites within the required range of the given point and time.

2.5 ELEMENT MAINTENANCE

2.5.1 Check List

2.5.1.1 Element set correction

2.5.1.2 SEAIC update

2.5.1.3 Bulletin, look angle generation

2.5.1.4 Sensor tasking

2.5.1.5 Element set correction

2.5.1.6 SEAIC update

2.5.1.7 Return satellite to DSSO

2.5.1.8 Unidentified observation association

2.5.1.9 Element set correction

2.5.1.10 Observation reduction

2.5.1.11 Element evaluation

2.5.1.12 Element adjustment

2.5.1.13 Least squares correction

2.5.1.14 Bulleting, look angle generation

2.5.1.15 Sensor tasking

2.5.1.16 Release bulletin and/or look angles

2.5.2 Task Description

2.5.2.1 Sufficient Observations

If sufficient observations are available, correct the last good element set (procedure 3.5), using selected observations (procedure 3.10) in the SGPDC program.

2.5.2.2 If the DC fails, evaluate the element set as in 2.5.2.11 below.

2.5.2.3 If the DC partially corrects the elements, re-evaluate the observations and compare the input elements with the output elements from the DC. Correct the better element set again (procedure 3.5) using the re-selected observations in the SGPDC program. This may be repeated as long as the SGPDC program appears to improve the elements.

2.5.2.4 If the DC is successful, updatethe System SEAIC files (procedure 3.3) using the SEAI program. The element set may be assigned the next usable number as catalogue elements, or may be identified alphanumerically as test elements. Test elements are considered less valid than catalogue elements.

2.5.2.5 Generate a bulletin (procedure 3.7) and look angles (procedure 3.8) if appropriate using the BLTNSGP and/or the GLASGP programs, OCS 17, or, if a d-term exists, the GLAP program.

2.5.2.6 Insure appropriate sensor tasking (procedure 3.6).

2.5.2.7 If additional observations are returned by the tasked sensors, correct the element set (procedure 3.5) using the selected and additional observations in the SGPDC program.

2.5.2.8 Update the System SEAIC files (procedure 3.3) using the SEAI program. If test elements were used they must be deleted and the old catalogue elements replaced with the new element set. Maintain the satellite until it can be returned to the DSSO for routine processing.

2.5.2.9 Insufficient observations

If sufficient observations are unavailable, associate the unidentified observations in the system (procedure 3.4) with the last good element set using the RASSN program in the SCHTP mode. The association parameters should have wide tolerances, and may warrant using a "blank" P-card.

2.5.2.10 Correct the element set using the SGPDC program as in 2.5.2.1 above.

2.5.2.11 If sufficient observations are still unavailable, or if for some other reason the DC fails, reduce all observations (procedure 3.4) against the best element set using the REDUCT program. An examination of past element sets may reveal the beginning of the disparity between the observations and the elements.

2.5.2.12 Examine the residuals output by the REDUCT program to determine the cause of the DC failure.

2.5.2.13 If the elements affected by the time equation appear valid, reselect the observations (procedure 3.10) and/or manually adjust one or more of the remaining elements (procedure 3.9) to facilitate successful differential correction.

2.5.2.14 Correct the element set again, as in 2.5.2.1 above, to generate the best possible element set on the satellite.

2.5.2.15 If the elements affected by the time equation appear invalid, or if too few observations exist to facilitate a successful DC, generate a delta t vs. revolution plot (procedure 3.10) of the residuals output by the REDUCT program. Determine the order of the equation describing the plot and the least squares points which define the plot.

2.5.2.16 Correct the element set (procedure 3.5) using the least squares points in the SYCHULL program.

2.5.2.17 Generate a bulletin (procedure 3.7) and look angles (procedure 3.8) if appropriate, as in 2.5.2.5 above.

2.6 DECAY PREDICTION

2.6.1 Check List

2.6.1.1 King-Hele/Findley estimate

2.6.1.2 Decay folder:

a. Satellite characteristics

b. SGPDC output

c. Sensor tasking messages

d. Bulletins released

e. Delta t vs. revolution, period vs. revolution or period vs. day plots

f. Look angles sets

g. King-Hele/Findley, Jacchia and other program predictions

h. Final decay message

2.6.1.3 Differential correction, bulletin and look angles

2.6.1.4 Sensor tasking

2.6.1.5 Released bulletin and look angles

2.6.1.6 Observation association and element correction

2.6.1.7 Jacchia prediction

2.6.1.8 Period vs. revolution or period vs. day plot

2.6.1.9 Observation reduction

2.6.1.10 Least squares correction, bulletin and look angles

2.6.1.11 Released bulletin and look angles

2.6.1.12 Delta t vs. revolution plot

2.6.1.13 Decay determination

2.6.1.14 Final decay message

2.6.2 Task Description

2.6.2.1 Estimate the decay day (procedure 3.11) using King-Hele/Findley program.

2.6.2.2 When the period is 90 minutes or less, initiate a decay folder on the satellite, to include:

a. Satellite characteristics: tumble rate, motion, size, shape and mass.
b. SGPDC output from a 90-minute period to decay
c. All sensor tasking messages
d. Bulletins released from a 90-minute period to decay
e. Look angles released from a 90-minute period to decay
f. Delta t vs. revolution and period vs. revolution or period vs. day plots.
g. King-Hele/Findley, Jacchia and other program predictions
h. Final decay message

2.6.2.3 Correct the latest element set (procedure 3.5) using all observations in the SGPDC program.

2.6.2.4 Generate a bulletin (procedure 3.7) and look angles (procedure 3.8) using the BLTNSGP and GLASGP programs (OCS 17).

2.6.2.5 Insure appropriate sensor tasking (procedure 3.6).

2.6.2.6 Release look angles to sensors.

2.6.2.7 Associate the additional observations (procedure 3.4) with the latest element set using the RASSN program.

2.6.2.8 Correct the latest element set (procedure 3.5) using the additional associated observations in the SGPDC program. Repeat the generation of a bulletin and look angles, sensor tasking, observation association and element set correction until:

a. The DC fails, or
b. The sensor system fails to return ovservations.

2.6.2.9 When estimated decay is less than one hundred revolutions away, predict the decay revolution (procedure 3.11) using period/revolution data in the Jacchia program; validate this by extrapolation of the curve on a manual plot of period vs. revolution.

3.2.10 When the DC fails, attempt to correct the elements (procedure 3.5) [illegible]ing a D_A term in the REDUCT-SYSBULL-GLAP program sequence.

3.2.11 Release look angles to sensors.

3.2.12 Manually generate a delta t vs. revolution plot (procedure 3.11).

3.2.13 When the sensor system fails to acquire the satellite in successive [illegible]tempts, the satellite may have decayed.

3.2.14 Examine the various decay predictions and, when they agree, deter[illegible]e the probable decay day and time (procedure 3.11) from:

a. Jacchia program prediction.

b. Manual plot of period vs. revolution and/or period vs. day.

c. Manual plot of delta t vs. revolution.

d. Time span between the last observation reported and the first predicted observation not reported.

3.2.15 Generate the final decay message (procedure 3.11), including:

a. SPADATS Object Number

b. Hours between which satellite probably decayed.

c. Day of probable decay.

d. Final bulletin indicator on this satellite.

Section 3

PROCEDURES

A variety of procedures are utilized to solve orbital determination problems. They appear in various tasks and in various combinations. A procedure may or may not involve the use of computer program support, and the fashion in which it is used may vary from task to task or from program to program. The relationship between the procedures and the six tasks described in Section 2 is shown in Figure 3-1.

The following procedures are included in this section:

Procedures		Tasks*					
No.	Title	1	2	3	4	5	6
1.	Nominal element set determination.	X	X				
2.	Initial element set determination.	X	X		X		
3.	SEAIC files update.	X	X	X		X	
4.	Observation association.	X	X	X	X	X	X
5.	Element correction.	X	X	X	X	X	X
6.	Sensor tasking.	X	X	X		X	X
7.	Bulletin generation.	X	X	X		X	X
8.	Look angle generation.	X	X	X		X	X
9.	Element set adjustment.	X		X		X	
10.	Observation selection.	X	X	X	X	X	
11.	Decay prediction						X
12.	Element conversion.						

Figure 3-1

Procedures and Related Tasks

*Note: Task titles:

1. Domestic Launch
2. Foreign Launch
3. Debris Separation
4. Proximity Determination
5. Element Maintenance
6. Decay Prediction

.1 NOMINAL ELEMENT SET DETERMINATION

.1.1 General

nominal element set is generated from predicted orbital values in order to rovide look angles to sensors so that the satellite can be tracked. Nominal lements are determined before each domestic launch and may be required for ccasional foreign launches for which initial observations are insufficient.

he nominal element set should contain values for the following orbital arameters:

a. Epoch year
b. P_A = anomalistic period, a = semi-major axis or q = perigee distance
c. i = inclination
d. e = eccentricity
e. T_0 = epoch time
f. ω_0 = argument of perigee
g. Ω_0 = right ascension
h. C = drag

.1.2 Domestic Launch Information

ational Aeronautics and Space Administration (NASA) or Space Systems Division SSD) of the U. S. Air Force usually supply pre-launch information before every aunch.

.1.2.1 Input

a. Date of launch
b. P_A
c. i (measured counterclockwise from the equator, east of the ascending node, to the orbit plane)
d. e
e. ϕ_I = latitude of injection (I)
f. λw_I = longitude west of injection
g. Direction of satellite motion at I: northerly or southerly

Any set of parameters which define an orbit (e.g., position and velocity vectors) may be used in place of P_A, i and e, with the proper formulas.

3.1.2.2 Processing

Upon receipt of pre-launch information on a domestic launch, determine a set of nominal elements in the standard format by manual calculation and by using the I.B.M. 1620 Computer Launch program. The two nominal element sets are compared and, if they do not agree, the disparities should be analyzed and adjusted.

3.1.2.2.1 To calculate the Argument of Perigee (ω_o) on revolution zero:

a. Calculate the distance (u) in the orbit from injection to the closest ascending node (actual or theoretical):

$\sin u = \dfrac{\sin \phi_i}{\sin i}$, if the direction of satellite motion at I is northerly.

$\sin (180^\circ - u) = \dfrac{\sin \phi_i}{\sin i}$, if the direction of satelllite motion at I is southerly.

b. Calculate the Argument of Perigee (ω_o) measured from the theoretical ascending node on revolution zero to the perigee point in the direction of satellite motion:

$\omega_o = u$, if I is in the northern hemisphere.

$\omega_o = 360^\circ - u$, if I is in the southern hemisphere.

NOTE: Perigee is assumed to occur at I.

3.1.2.2.2 To calculate the time (T_0) of the satellite's imaginary passage through the ascending node on revolution zero.

a. Calculate the Eccentric Anomaly (E):

$\tan \dfrac{E}{2} = \tan \dfrac{\omega_o}{2} \sqrt{\dfrac{1 - e}{1 + e}}$, if $0^\circ \leq \dfrac{\omega_o}{2} \leq 90^\circ$, then $0^\circ \leq \dfrac{E}{2} \leq 90^\circ$

$\cot \left[\dfrac{E - 180^\circ}{2}\right] = \cot \left[\dfrac{\omega_o - 180^\circ}{2}\right] \sqrt{\dfrac{1 - e}{1 + e}}$, if $90^\circ < \dfrac{\omega_o}{2} \leq 180^\circ$, then $90^\circ < \dfrac{E}{2} \leq 180^\circ$

b. Calculate the Mean Anomaly (M):

$M^o = E - \left[(e \sin E)(57.3)\right]$ There are 57.3 degrees per radian.

c. Calculate the time difference (Δt) between T_o and the time of injection (T_i):

$$\Delta t = \frac{P_a M^o}{360^o}$$

d. Calculate T_i (in days since 1 January):

T_i = Time of lift-off (in days since 1 January) + Time from lift-off to injection (in fractions of a day)

NOTE: If time from lift-off to injection is given in seconds, divide by 86,400.

NOTE: Nominal time of lift-off is assumed to occur at 0000Z on the day of launch.

e. Calculate T_o:

$T_o = T_i - \Delta t$

3.1.2.2.3 To calculate the right ascension (Ω_o) on revolution zero, (measured eastward from the vernal equinox to the ascending node):

a. Calculate the right ascension of zero longitude (Greenwich) at T ($\Theta_{G_{T_O}}$), with right ascension of zero longitude at 0000Z on 1 January, 1964 (Θ_O) = 98.74077.

$\Theta_{G_{T_O}} = \Theta_O + [360^o$ times the fractional part of $(T_O \cdot 1.00273791)]$

b. Calculate the difference in longitude ($\Delta\lambda$) between injection longitude (λ_{w_i}) and the closest ascending node (actual or theoretical), measured in a westward direction from Greenwich:

$\cos \Delta\lambda = \dfrac{\cos u}{\cos \phi_i}$, if $u \leq 90^o$.

$\cos (180^o - \Delta\lambda) = \dfrac{\cos (180^o - u)}{\cos \phi_i}$, if $90^o < u \leq 180^o$.

d. Calculate the longitude of the theoretical ascending node (λ_{w_o}) on revolution zero:

$$\lambda_{w_o} = \lambda_{w_i} \pm \Delta\lambda - \overline{ER}$$

NOTE: The signs of $\Delta\lambda$ and 360^o can be determined from the following table, where P = prograde and R = retrograde satellite motion, and N = northern hemisphere and S = southern hemisphere injection latitude. Addition or subtraction of 360^o, where indicated in the table, will not change the value of ($\lambda_{w_i} \pm \Delta\lambda - \overline{ER}$)

	P		R	
	$\Delta\lambda$	360^o	$\Delta\lambda$	360^o
N	+		-	
S	-	+	-	+

e. Calculate Ω_o:

$$\Omega_o = \theta_{G_{T_o}} - \lambda_{w_o}$$

3.1.2.2.4 Determine the drag term (C):

a. Enter the C-term plot (Figure 3-2) with perigee height <u>above</u> the earth's surface and eccentricity.

b. Read the C-term base number from 1 to 0 (left to right) between the two appropriate contours.

c. Read the C-term exponent number (to the base 10) between the two appropriate contours at the top of the plot.

For example, if e = 0.2 and ER = 1.03, C = -0.7×10^{-6}. If e = 0.08 and ER = 1.06, C = -0.0×10^{-7} or -1.0×10^{-8}. The fractional part of the perigee height represents the distance above the earth.

3.1.3 Foreign Launch Information

Pre-launch information on foreign launches is usually unavailable. However, initial observations may come from three types of sensors.

3.1.3.1 Input

a. Radar fan data: time, azimuth, elevation, range and range rate (optional)

b. Tracker data: time, azimuth, elevation, range and range rate

c. Telemetry data: time, azimuth and elevation

3.1.3.2 Processing

If telemetry or tracker data are received on a foreign launch, an initial element set is computed (procedure 3.2). If radar fan data only are received, manually generate an element set.

There are several predetermined element sets which have been computed from previous foreign launches. These may be used as nominal element sets for succeeding launches. Attempt to associate initial fan data with fan data on previous launches to facilitate selection of one of the nominal element sets. If the initial observations do associate, use the selected nominal element set until additional observations are received. If the additional observations associate closely with the nominal element set (procedure 3.4), it is corrected (procedure 3.5). Otherwise, the additional observations should be used to compute an initial element set (procedure 3.2).

When the initial fan data does not associate with any historical data, attempt to calculate an initial element set (procedure 3.2) using the initial fan data and other available information.

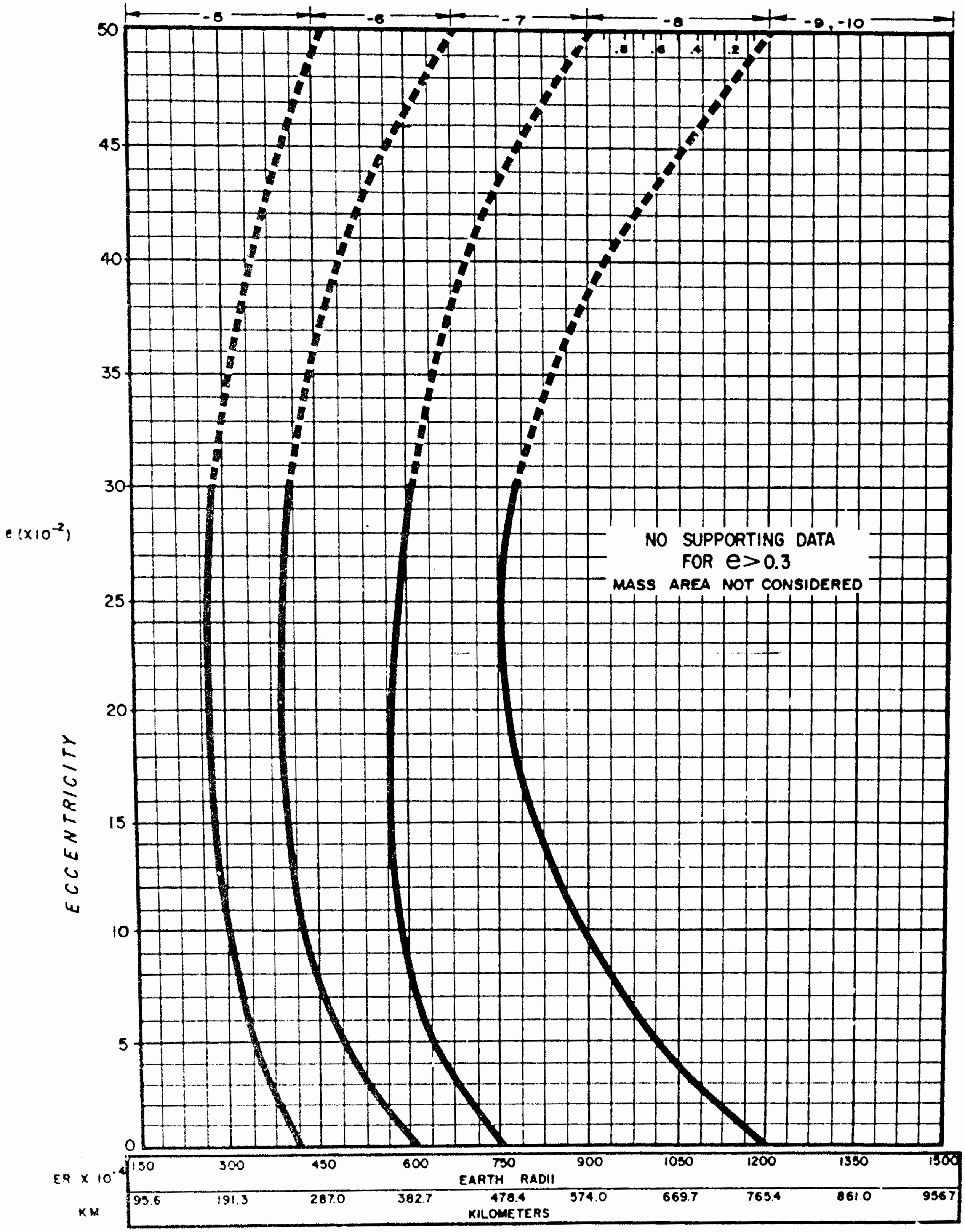


FIGURE 3-2
C-TERM GRAPH

3.2 INITIAL ELEMENT SET DETERMINATION

3.2.1 General

An initial element set is determined from initial observations in order to provide look angles to sensors so that the satellite can be tracked. This occurs primarily on foreign launches.

3.3.2 Foreign Launch Information

Initial observations on foreign launches usually come from three types of sensors.

3.2.2.1 Input

a. Radar fan data: time, azimuth, elevation, range and range rate (optional)

b. Tracker data: time azimuth, elevation, range and range rate

c. Telemetry data: time, azimuth and elevation

3.2.2.2 Processing

Upon receipt of radar fan data on a foreign launch, attempt to associate the initial fan data with fan data on previous foreign launches (procedure 3.1).

If the initial observations do not associate, attempt to calculate an initial element set using the initial observations and other selected information. The procedure for this calculation follows as closely as possible the procedure for calculating a nominal element set based on U.S pre-launch information (procedure 3.1). Lack of complete information, however, may require that a value be assumed for one or more of the elements on a trial basis. Continue to manually adjust the initial element set, until sufficient observations are received to provide for a reliable differential correction (procedure 3.5).

Upon receipt of tracker data on a foreign launch, the Initial Orbit by Herrick-Gibbs (IOHG) program is used to compute the initial element set. The IOHG program uses three three-dimensional fixes from one sensor to compute the initial element set. The program automatically uses all remaining observations to differentially correct that element set (by the Simplified General Perturbations method).

Upon receipt of telemetry data on a foreign launch, the Initial Orbit from Angular Fixes (IOANGLE) program is used to compute the initial element set. Three angular position fixes from one sensor are used in the computation and the remaining observations are utilized in a differential correction. Basically the same methods as in the IOHG program are employed for both element set computation and differential correction.

If only geocentric rectangular coordinates and velocity data are available on a launch, the Radar Orbit Computation (ROC) program is used to compute the initial element set. No differential correction is included in this program.

If two or more radar fixes only are available on a launch, use the Initial Orbit from Independent Radar Fixes (IORF) program to compute the initial element set. These fixes may be isolated radar hits which come from different stations or which occur during different revolutions. Differential correction is not included in this program.

3.3 SYSTEM SEAIC FILES UPDATE

3.3.1 General

Sensor, Element, Acquisition, Information and Communication data are maintained on all satellites carried by the SPACETRACK Center. This data is maintained on punched cards in the System SEAIC files. It is also stored on the SEAIC tape for most satellites, because many of the programs accept SEAIC tape inputs. The SEAI Tape File Maintenance program is used to add, modify or delete information from the SEAIC tape.

3.3.2 Foreign Launch

Upon establishing the first acceptable element set on a foreign launch, the E, A and I files on the satellite are added to the SEAIC tape to facilitate the generation of a bulletin and look angles. The Special Foreign SEAI Tape File Maintenance program is used because it includes a predetermined acquisition and information file especially designed for foreign launch.

3.3.2.1 Input

a. Classification

b. Precedence

c. Launch area

d. FLASH bulletin indicator (optional)

e. Satellite transmitting indicator (optional)

f. Element set

3.3.2.2 Processing

The Special Foreign SEAI Tape File Maintenance program adds the E, A and I files to the SEAIC tape and automatically enters the bulletin and look angle generation procedures (procedures 3.7 and 3.8). A and I-file cards should be punched so that the information on the SEAIC Tape is also in the card files.

3.3.3 Domestic Launch

Upon determination of a nominal element set on a domestic launch, request that a special SEAIC tape be built. This special tape is used until after the satellite is launched and an acceptable element set determined.

3.3.3.1 Input

a. Sensor data

b. Nominal Element Set

c. Acquisition data - usually from the Operations Division

d. Information data - usually from the Operations Division

3.3.4 Satellite Maintenance

After a reliable element set for any satellite has been determined, the element set is maintained in the System SEAIC files. Subsequent changes to the element sets are made manually or automatically, depending on the stability of the satellite and the reliability of the element set.

3.3.4.1 Input

a. Element set

b. Acquisition data

c. Information data

3.3.4.2 Processing

If the element set is corrected by the Simplified General Perturbation Ephemeris with Differential Correction (SGPDC) program in the automatic mode, the new element set will be stored on the SEAIC tape in place of the old element set provided convergence occurs on all six elements and the drag term (procedure 3.5). Otherwise, the old element set remains on the SEAIC tape. If the SGPDC program is used in the Schedule Tape mode, the SEAI Tape File Maintenance program is used to update the SEAIC tape (procedure 3.3).

3.3.5 SEAI Tape Files Maintenance

Additions and or deletions may be made to the S-file, E-file, A-file and I-files using the SEAI Tape File Maintenance program with the appropriate S, E, A or I-file card or the SEAI File Deletion card.

3.4 OBSERVATION ASSOCIATION

3.4.1 General

Observations received by the SPACETRACK Center must be associated with a satellite before they can be used to correct the element set describing that satellite.

3.4.2 Gross Association

The gross association of observations with a satellite is accomplished by identifying those observations which fall in a specified time span. The time span is usually that during which the satellite is expected to be within the acquisition capability of the sensor which returned the observations.

3.4.2.1 Input

a. Observation(s)

b. Association criteria - e.g., time span

3.4.2.2 Processing

When large masses of data are received, as from BMEWS, the Observation Separation (OBSSEP) program is used to separate the observations into two groups according to the time span indicated. The OBSSEP program outputs the observations falling within the time span on a high priority Report tape (R-tape) and those falling outside the time span on a low priority R-tape. When only a few observations are involved, the observation times may be examined visually.

3.4.3 Routine Association

The Report Association (RASSN) program is used to accomplish the routine association of observations with a satellite.

3.4.3.1 Input

a. Observation data

b. Sensor data

c. Element set

3.4.3.2 Processing

The RASSN program may be run in the automatic or the Schedule Tape mode. In the automatic mode the program attempts to associate all observations with all satellites on the SEAIC tape. In the Schedule Tape mode the program attempts to associate all observations with those satellites for which element sets are input.

The program assigns one of three levels of association to each observation and identifies the satellite with which it is associated. The levels of association are Associated (Ra), Doubtful (Rd) and Unassociated (Ru).

3.4.4 Special Association

Special association of observations with a satellite may be required whenever the association parameters in the RASSN program are too open or too restricted for accurate association to occur.

3.4.4.1 Input

a. Observation data
b. Sensor data
c. Element data
d. Association parameters

3.4.4.2 Processing

Either the RASSN or the Reduction (REDUCT) program may be used to achieve association under special conditions.

The RASSN program, run in the Schedule Tape mode, requires specification of the numerical values of the association parameters (time, right ascension, height, vector magnitude and beta). The program tags each observation as associated or unassociated.

The REDUCT program reduces observations back to the last nodal crossing and computes the residual differences between the observations and the elements in terms of time, right ascension and height. The program then identifies those observations whose residuals fall within one of several sets of tolerance limits contained in the program. The limits are specified each time the program is run.

The residuals output by the RASSN or REDUCT program may be used to further refine the association levels of the observations (procedure 3.10).

3.5 ELEMENT CORRECTION

3.5.1 General

The purpose of element correction is to refine an element set, making use of observations received since the preceding correction, so that the resultant element set more nearly represents the actual motion of the satellite.

3.5.2 Complete Correction - anomalistic data

A complete differential correction of an element set corrects all six elements and the drag term.

3.5.2.1 Input

a. Observation data

b. Sensor data

c. Element set

3.5.2.2 Processing

The SGPDC program attempts to differentially correct all of the six orbital elements and the drag parameter. In case the attempt to converge on these seven parameters fails, the program automatically tries to converge on a fewer number. The program is designed to handle most satellites having zero to moderate eccentricity. Secular variations due to the earth bulge and atmospheric drag are accounted for directly. The perturbations due to solar radiation pressures and gravity fields of the sun and moon are neglected analytically; however, any long term effects of these perturbations are included in the element corrections obtained by the least squares error process. The SGPDC program does not compute the first derivative (D) of the drag term (C).

3.5.3 Partial Correction (Time equation only)-nodal data

Partial correction of an element set corrects only those parameters affecting the time of crossing the ascending node: T_0, P, C, and D (the first derivative of C).

3.5.3.1 Input

a. Element set

b. Time residuals at specific revolutions

c. Order of the equation to be fit - linear, quadratic or cubic

3.5.3.2 Processing

The System Bulletin (SYSBULL) program may be used to correct an element set before producing a bulletin. The program computes a least squares fit to the time equation from time residual inputs. These residual values usually come from the output of the REDUCT program (procedure 3.4) and the order of the equation is determined by examination of the time residuals plotted against their revolution number (procedure 3.10).

3.6 SENSOR TASKING

3.6.1 General

A priority for observing a particular satellite and the amount of data to be reported may be specified by insuring that the proper sensors are tasked at the proper levels.

3.6.2 USAF Sensors

There are three priority levels and three data levels.

Tasking Priority	Meaning
1	Observations on emergency or extremely high priority space events.
2	High priority observations on selected satellites.
3	Routine observations on selected satellites.

Data Suffix	
A	Send all possible position data from the time of acquisition until the object passes beyond the sensor capability.
B	Send all position data obtainable during a period not to exceed 3 minutes
C	Send best single observation.

3.6.3 NAVSPASUR Sensors

Tasking Category	Meaning
1	All observations referenced to applicable receiver stations are reported by telephone and followed by an "Immediate" precedence message as soon as possible.
2	All observations referenced to applicable receiver stations are reported by "Priority" precedence message as soon as possible.

Tasking Category	Meaning
3	All multi-station observations referenced to Kickapoo site and all single observations referenced to applicable receiver stations are reported by "Routine" precedence message every 8 hours.
4	Same as Category 3: every 24 hours.
5	Same as Category 3: excluding single observations, every 24 hours.

Categories 1, 2, and 3 are in effect the same as the present Category 1, 2, and 3 used with USAF Sensors when applied to new foreign launches (Category 1) and new domestic launches (Category 2). Therefore, all pre-printed message forms will include SPASUR as addressee on the initial alert messages from NORAD SPADATS for both foreign and domestic launches. Suffixes A, B, and C do not apply to NAVSPASUR and they have been advised to disregard the suffix on multiple addressed messages.

Categories 4 and 5 will be primarily used by the Data Control/Sensor Branch when assigning routine monthly tasking through NORAD SPADATS. However, sensor tasking may be changed, on routine type satellites, to Category 4 or 5 when applicable.

3.7 BULLETIN GENERATION

3.7.1 General

A bulletin (ephemeris) contains predicted satellite position information. Future satellite positions are extrapolated from an element set best fitting the current and past satellite observations.

3.7.1.1 Input

a. Element set

3.7.1.2 Processing

There are two methods of generating a bulletin. Normally the Bulletin with Simplified General Perturbations (BLTNSGP) program is used to generate a bulletin. If the SYSBULL program is used to correct the element set, it will produce a bulletin automatically, and unlike BLTNSGP, will use the D term. The BLTNSGP program uses anomalistic data, whereas the SYSBULL program uses nodal data.

Both programs compute essentially the same information:

a. An element set at the time of crossing the ascending node for the epoch revolution.

b. Position and time of crossing an ascending node for all revolutions covered by the bulletin.

c. Position, time and height at consecutive latitudes covering one entire revolution.

In addition, the BLTNSGP program prepares a modified description of the orbital elements, which is used for special prediction purposes as specified in the International Geophysical Year (IGY) World Wide Code for Satellite Orbits (SATOR).

3.8.3.1 Input

a. Sensor data

b. Element set

c. Acquisition data

3.8.3.2 Processing

The GLAP program will compute a set of acquisition coordinates for each satellite and the associated sensors. The program computes look angles for general acquisition purposes.

3.9 ELEMENT SET ADJUSTMENT

3.9.1 General

When excessively large residuals exist, manual adjustment of the affected element value may provide for a successful differential correction using routine procedures.

3.9.2 Foreign Launch Data

If the initial observations are insufficient to compute or calculate an initial element set, or if the initial observations will not associate with any of the nominal element sets, adjust one or more of the element values in the closest nominal element set on a trial basis, and attempt to associate the initial observations with this adjusted nominal element set.

3.9.3 Domestic Launch Data

Following a domestic launch the nominal elements (Ω_0 and T_0) are manually adjusted to reflect the actual lift-off time.

3.9.4 Unusual Orbital Data

It is sometimes difficult to maintain a reliable set of orbital elements on a satellite with an unusual orbit. Observations may no longer be received or the elements may not converge on the observations available in a differential correction (procedure 3 5). Occasionally all but one or two of the elements converge on the observations, indicating that the observations are reliable but that one or more of the element values may be in error. Adjust the apparently erroneous element values and attempt to attain convergence on all the elements in another differential correction.

3.10 OBSERVATION SELECTION

3.10.1 General

Removal of doubtful or erroneous observations from a group of data will usually facilitate a more accurate differential correction. Particular observations are often selected from those available because they reflect a major trend, evenly represent an entire orbit or indicate a different but associated orbit.

The methods of observation selection are manual. In clear-cut cases, identify observations by a visual examination of the hard copy produced by one of the association programs. Otherwise plot the observations on a graph, in terms of their deviations in observation time (delta t) or right ascension (Ω_0) from predicted values, as a function of revolutions. The groupings of residuals may reveal the source of a problem in the maintenance of reliable elements. The output of the REDUCT program (procedure 3.4) is often used to provide the data for such a graph.

3.10.2 Initial Observations

Initial observations on a newly launched satellite usually reflect a major trend. Elimination of those observations which deviate from such a trend tends to improve the computed element set. (procedure 3.2)

3.10.3 Element Set Variations

Observations on a satellite often reflect a slight change in the orbit of the satellite by their general trend. A review of delta t vs. revolution using all the observations sometimes indicates a break in the general trend. If earlier observations (prior to the trend change) are eliminated, the most recent element set can be differentially corrected (procedure 3.5) using only the recent observations, which represent the latest changes in the orbit.

3.10.4 Observations on an Unusual Orbit

Satellites having unusual orbits often reflect one or more of the following:

a. High eccentricity
b. Low inclination
c. Small radar cross-section
d. Perigee in southern hemisphere
e. Large period
f. Small period (e.g., approaching decay)
g. High drag
h. Element set errors

When a satellite has an unusual orbit, sensor coverage is generally marginal. Thus the observations reported often represent a few unequally distributed points in the satellite orbit. A group of selected observations, evenly representing the entire satellite orbit, usually provides a better correction of the element set.

3.10.5 Observations on Associated Bodies

When part of the main body of a satellite breaks off or is separated in the form of debris, the debris observations are often not as numerous as the larger body observations. However, debris observations are usually received about the same time as the main body observations, and may associate partially or completely with the main body element set. Debris observations deviate mainly in their time residuals and, for a particular piece, these deviations are consistent. The use of only debris observations in differentially correcting the main body element set provides an element set on the debris object. The main body element set before correction is retained to represent the main body of the satellite.

3.10.6 Unidentified Observations

Occasionally there are too few observations associated with an element set to provide for adequate correction of the element set. Some of the unidentified observations in the system, which did not associate with the

element set using routine procedures, may in fact represent the satellite.

Observations received during a particular time period over a specific sensor may be selected manually or by use of the OBSSEP program. Next, they are associated with those observations which do not associate with any other satellite, and then examined for possible association with a given element set.

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3.11 DECAY PREDICTION

3.11.1 General

A satellite is removed from the system when it has reentered the earth's atmosphere or is no longer in orbit. Decay prediction is seldom exact, so several methods should be used simultaneously.

3.11.2 Initial Decay Indications

The Duty Space Surveillance Officer (DSSO) usually forecasts satellite decay by a period check. The satellite is then transferred to the Analysis Division for maintenance until it has decayed.

3.11.2.1 Input

a. Element set

b. Probable decay indication:

   1. Period less than 90 minutes or

   2. Decrease in period and eccentricity, and elements that hold for only a few days.

3.11.2.2 Processing

Determine a probable decay day by running the King-Hele/Findley program with the element set, or by examining the results of the last King-Hele/Findley run on this element set, which the DSSO initiated before transferring the satellite to the Analysis Division. A revolution vs. day plot is generated to substantiate the King-Hele/Findley predictions.

3.11.2.3 Output

The King-Hele and Findley routines both predict a decay day.

3.11.3 Final Decay Indications

The approach of final decay is indicated by the period, the rate of change of the period and the satellite characteristics (tumble rate, motion, size, shape and mass). Maintenance of the satellite requires greater attention especially when decay appears to be less than 100 revolutions away. Careful selection of observations may substantially improve the element set.

3.11.3.1 Input

a. A graph of the difference between predicted and reported observation time for each revolution (delta t vs. revolution.)
b. A graph of the period for each revolution (period vs. revolution or day)
c. Satellite characteristics - tumble rate, motion, size, shape and mass.

3.11.3.2 Processing

There are four methods of predicting decay:

a. Run the Jacchia program using the periods and corresponding revolution.
b. Manually extrapolate the period on the period vs. revolution or day graph, and compare the results with those of the Jacchia program.
c. Examine the delta t vs. revolution graph for a break in the curve. This curve usually becomes cubic in shape and, just before final decay, the rate of decrease of delta t increases so sharply as to deviate from a cubic curve and approach a logarithmic curve.
d. Identify that time span between the last observation reported and the first predicted observation not reported. This is only as reliable as the element set used to generate the look angles for the sensors.

Usually all four methods are used, and Jacchia may even be run several times using different sets of periods, to determine a predicted range of revolutions within which to expect final decay. If results of the various methods agree, the analyst may conclude that final decay has occurred when the first tasked sensor fails to report an observation. Otherwise the analyst may wait until several tasked sensors have failed to observe the satellite.

Occasionally satellites decay shortly after launch or are deorbited. Time for decay prediction is not available and the time of decay is often reported by an outside agency.

After final decay has been concluded, initiate the final decay message and remove the satellite from the SEAIA files.

3.12 ELEMENT CONVERSION

3.12.1 General

Elements received from external agencies (NASA, 6594th Aerospace Test Wing, Sunnyvale, NAVSPASUR) must be converted to a form useable by SPACETRACK. The procedure for making the necessary adjustments is outlined below. It should be noted that epoch times shown are not necessarily for a nodal crossing as used by SPACETRACK, but are usually defined for some arbitrary point in the orbit. The epoch time is measured at some point beyond perigee and the satellite position at epoch is given by the mean anomaly, M.

3.12.1.1 Input

a. Orbital element set.

3.12.1.2 Processing

First, determine the time from perigee to the next nodal crossing. This is done by subtracting the argument of perigee (ω) from 360°. Figure 3-3 is a geographical representation of the problem.

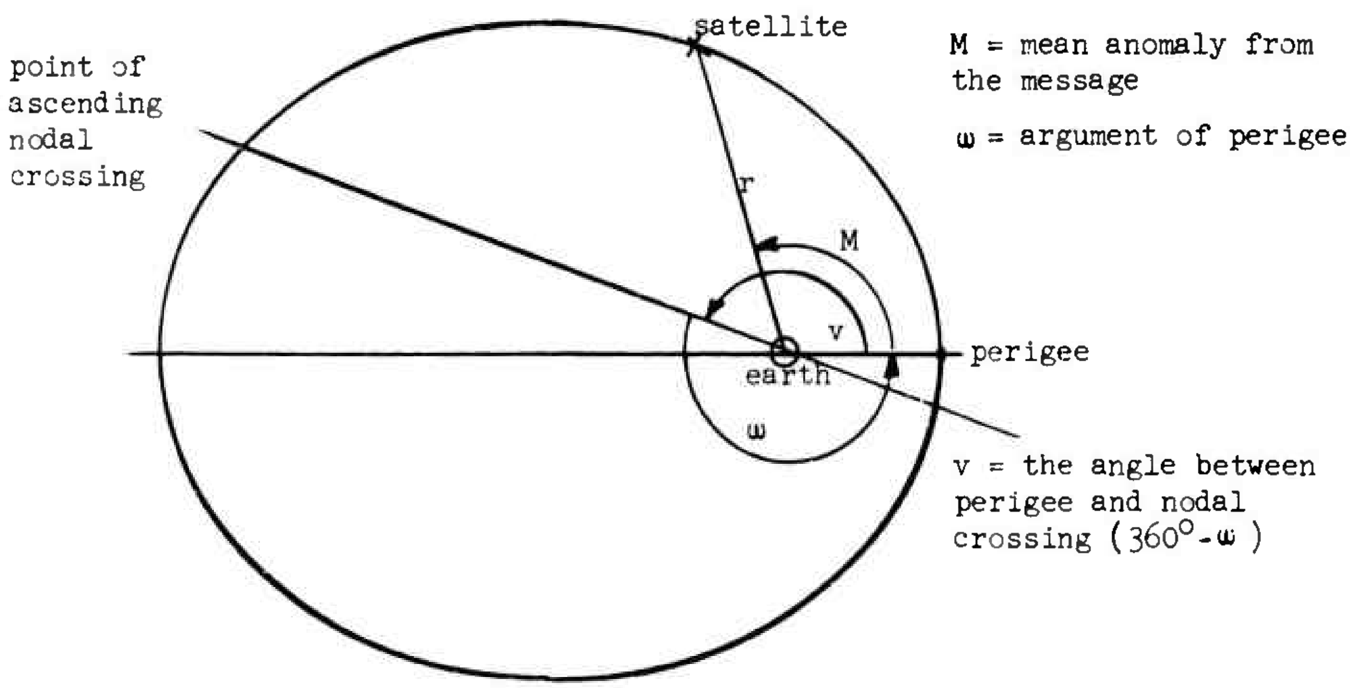

Figure 3-3

Let the quantity obtained above equal v, and, by substituting in equation 1, determine the eccentric anomaly, E.

(1) $\cos E = \frac{e + \cos v}{1 + e \cos v}$, where e = eccentricity

Calculate the mean anomaly, M_n by equation (2):

(2) $M_n = E - e \sin E \, (57.3^\circ)$,

Then, by substitution in (3) determine M_t, (total change in mean motion from old epoch to new epoch)

(3) $M_t = M_n - M$, M = mean anomaly from the message

The time of the epoch in the message may now be changed to the time of the ascending node by using equation (4) and (5).

(4) $\Delta t = \frac{M_t}{360^\circ} P_A$, P_A = anomalistic period from the message

(5) $T_o = T_m + \Delta t$, T_o = nodal epoch time

T_m = message epoch time

The right ascension of the ascending node at T_o must now be corrected, using the right ascension (Ω) to calculate a new right ascension (Ω_o).

(6) $\Omega_o = \Omega + \dot{\Omega} \Delta t$, where: Ω = right ascension from message.

Ω_o = right ascension of nodal crossing.

$\dot{\Omega}$ = right ascension motion.

Since the argument of perigee is given for a nodal crossing on SPACETRACK elements the argument of perigee on the message must be changed by equation (7).

(7) $\omega_o = \omega + \dot{\omega}\Delta t$, where ω_o = new argument of perigee.

ω = argument of perigee from the message.

$\dot{\omega}$ = argument of perigee motion.

Next, perigee distance and semi-major axis must be converted into earth radii. Finally, a new epoch revolution number should be calculated. This can be obtained from an old bulletin, or from the time equation (8).

(8) $T = T_o + P_N \Delta N + C (\Delta N)^2 + D (\Delta N)^3$

Section 4

PROGRAMS

The programs in the B-2 System are organized into six functional areas:

a. Executive

b. Association

c. Element Determination

d. Observation Acquisition

e. Interplanetary

f. Miscellaneous

A seventh group consists of programs for use on the 1620 computer.

Card and deck input formats are specified and outputs described for the programs most frequently used by the analyst. The purposes of the less used programs appear at the end of their appropriate functional area.

Following the program sections are descriptions of OCS sequences, Schedule Tape requirements and standard card formats.

4.1 EXECUTIVE AREA

The executive area of the B-2 System is composed of a real-time subsystem (BMEWS and INTPROC), a non-real-time subsystem (EXECMOD1, SYMOCT, EXECMOD2, and EXECMOD3), and an initialization subsystem (BSTARTUP and BRSTART). The real-time executive subsystem provides for BMEWS DIP backup while the non-real-time executive subsystem provides control for the Space Track programs.

There are two modes of operating the B-2 System:

a. Interruptable - Space Track and BMEWS DIP backup

b. Non-interruptable - Space Track only

The BSTARTUP program is used to initialize the B-2 System when running in the interruptable mode. The BRSTART program is used to re-start the system when a machine malfunction has occurred in the real-time area of core. The INTPROC program provides the capability to interrupt a Space Track program and perform BMEWS DIP backup, and then return to the interrupted program without loss of data. The BMEWS program provides duplicate backup for the BMEWS DIP processor, under the control of the INTPROC program.

The primary non-real-time executive program is EXECMOD1, which contains the basic routines that are required for operator control of the Space Track System. The EXECMOD2 program provides control of OCS and Schedule Tape runs, including program environment and system tape control. EXECMOD3 is the Schedule Tape executive program. It is used for converting control cards and data cards stored on the schedule tape, and for storing them in core in a format acceptable to the other system programs. It also transfers data from the prestored schedule tape to a data input tape when data for a manual program is interpreted. After the data cards have been converted, control is returned to EXECMOD2 where the specified program is read in and operated. The SYMOCT program converts mnemonic octal corrections from a prestored tape to a format acceptable to the central computer. The program operates as a closed subroutine of the EXECMOD1 program.

4.2 ASSOCIATION AREA

The Association area includes the input conversion programs (MAP and ORCON), the association sequence programs (RASSN, RTPJUG, SRTMRG and SRCHEK), another association program (REDUCT) and observation file maintenance programs (OPURGE, OBSSEP, SRADU, RUMOV, PRINTER, GOODER and OBSEND).

4.2.1 REPORT ASSOCIATION - RASSN

4.2.1.1 Purpose

The RASSN program associates each of the observations with the element set as Associated (Ra), Doubtful (Rd) or Unassociated (Ru). The classification is based on a comparision of the residuals against specified criteria.

These criteria are specified by the Analyst when in the Schedule Tape Mode. In the Automatic Mode, the criteria are contained within the program with the following values:

Δt = 2 min.
RA = Not tested.
ΔH = Not tested.
VM = 1000 km.
β = $.2^{\circ}$

4.2.1.2 Input

4.2.1.2.1 Automatic Mode - in an OCS sequence

a. Observations from the R-tape.
b. Element sets from the E-file tape.
c. Sensor coordinates from the S-file tape.
d. OCS Toggle number = Desired OCS sequence.

4.2.1.2.2 Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-13	RASSN

Deck Position	Card Type	Column Number	Punch
		17	0 = Element Set cards, S-file and R-tape inputs.
			1 = Observation cards, S-file and E-file inputs.
			2 = Parameter card, Satellite Number card and S-file, E-file and R-tape inputs.
			3 = Element Set cards, Observation cards, and S-file tape inputs.
			4 = Parameter card and S-file, E-file and R-tape inputs.
			5 = Parameter card, Observation cards and S-file and E-file tape inputs.
			6 = Parameter card, Element Set cards, Observation cards and S-file tape inputs.
			7 = Parameter card, Element Set cards and S-file and R-tape inputs.
		18	0 = Sorted/Merged, Hardcopy and residual cards output.
			1 = Sorted/No Merge, Hardcopy and residual cards output.
			2 = No Sort/No Merge, Hardcopy output.
			3 = No Sort/Merged, Hardcopy output.
		80	J = Card type.

Deck Position	Card Type	Column Number	Punch
5	Parameter Card		
		1-8	Delta T limit (max. = 1440 min.)
		9-16	Delta RA limit (max. = 360°)
		17-24	Delta H limit (max. = 6378 km.)
		25-32	Vec. Mag. limit (max. = 10^{10} km.)
		33-40	Beta limit (max. = 90°)
		80	P = Card type

NOTE: Any unspecified limit (blank cols.) is assumed to contain its maximum value.

6 Data Cards:

a. Input Option 0:
   (1) Element Set cards
b. Input Option 1:
   (1) Observation cards
c. Input Option 2:
   (1) Parameter card
   (2) Satellite Number card
d. Input Option 3:
   (1) Element Set cards
   (2) Observation cards

Deck Position	Card Type	Column Number	Punch
	e. e. Input Option 4:		
	(1) Parameter card		
	f. d. Input Option 5:		
	(1) Parameter card		
	(2) Observation cards		
	g. e. Input Option 6:		
	(1) Parameter card		
	(2) Element Set cards		
	(3) Observation cards		
	h. f. Input Option 7:		
	(1) Parameter card		
	(2) Element Set cards		
7	End of Case Card		
8	End of Job Card		
9	End of Schedule Tape Card		
10	Blank Card		

4.2.1.3 Output

4.2.1.3.1 Normal RASSN

The ordering of the printed output from RASSN may be made in two forms, sorted and unsorted. For sorted output associated (Ra) and doubtfully associated (RD) observations are printed first and listed in the order received from the R-tape. The unassociated observations are printed in the second section of printout in chronological order. In the unsorted form, all reports are output in the order processed.

The quantities printed are:

1. association status (STATUS)

   1 = Ra for radar report

   2 = Rd for radar report

   3 = Ru for radar report

4 = Ra for angles only report

5 = Rd for angles only report

6 = Ru for angles only report

7 = Ra for range rate report*

8 = Ru for range rate report*

2. tag (association made by sensor - OSAT)
3. sensor number (STAT)
4. observation time (last digit of year, month, day, hour, minutes, seconds and hundredths of seconds YYM DD HHMMSS.SS)
5. association number (satellite number with which the observation has been associated; blank for Ru's - NSAT)
6. message number (if present; MSGNO)
7. revolution number and element set number (Ra & Rd only; REV EL)

The remaining quantities vary with the type of association status and are as shown below

STATUS	QUANTITIES PRINTED
1	U_o Δt, vector magnitude, β, time since epoch
2	Uo, Δt, vector magnitude, β, $\Delta\rho$, Δh, ΔA cos h, time since epoch
3	$\emptyset$, λ, H, A, h, ρ, sidereal time
4	U_{ho}, Δt_h, vector magnitude, β, time since epoch
5	U_{ho}, Δt_h, vector magnitude, β, time since epoch, $\Delta\delta$ and $\Delta\alpha$ cos δ, or Δh and ΔA cos h
6	δ and α or h and A
7	$\Delta\dot{\rho}$, tag = association number, time since epoch
8	$\dot{\rho}$

* currently not used

where U_o = argument of latitude

Δt = observed minus predicted difference in time (minutes)

Vector Magnitude = magnitude of vector distance between observed and predicted positions (km)

β = "out of plane" angle

ρ = range

$\dot{\rho}$ = range rate

$\Delta\rho$ = observed minus predicted range

h = elevation

Δh = observed minus predicted elevation

δ = declination

$\Delta\delta$ = observed minus predicted declination

α = right ascension

$\Delta\alpha \cos \delta$ = observed minus predicted right ascension

A = azimuth

$\Delta A \cos h$ = observed minus predicted azimuth

Δt_h = Δt computed from elements

ΔU_{ho} = ΔU_o computed from elements

If on the same observation there are two or more doubtful associations, they are printed in the output. The best doubtful, based on the lowest vector magnitude, is marked with an asterisk next to association status. A tagged observation whose tag is changed in processing is shown first as a doubtful association with a question mark next to association status. As many residuals as have been computed are printed; those not computed at the time of untagging are shown as zero.

SAMPLE PRINTOUT, RASSN

```
S                                                                                                                PAGE  1
T OSAT STAT YMM DD HHMMSS.SS     DT     U  BETA VEC-MAG    DRANG    DELEV DACOSH TI-TO    ALT       RANGE   ELEV     AZIM
A                                MIN   DEG  DEG    KM        KM      DEG    DEG    DAYS   KM          RM     DEG      DEG
T NSAT OBSN  MSGNO     REV    EL                            DELH   DELRA                    LAT  LONG  SID.T RRAT    DRR
U                                                                                           DEG   DEG  HH MM  M/S    M/S
S

1 000    328 401 19 213037.42   -.56   84 -.13     274                              .81
  681  28413           1310   24

3 000    329 401 19 212951.98                                                            582.0    2128.8    6.8 346.1
       28412                                                                            80.5 184.8  19 26

2 000    329 401 19 211756.42   -.01   65 -.07     111      -7.6     .0     -.1  21.56
  548  28396          13301    6

2*000    329 401 19 211410.30   -.43   85  .01     191    -173.1    1.6     -.5   7.85
  236  28385          13563   47

2 000    329 401 19 211410.30   -.57   85  .31     293    -293.0     .0      .2  18.72
  542 28385           12680    7

4 004    033 401 19 031210.92    .03  107 -.03      13                                 1.33
  004 29245  00000    26131 297

5?004    041 401 18 145525.24    .00   94 -.05      11              -1.3    -2.8    .82
      29252  00000        0 297

4 004    041 401 18 145525.24   -.05  125 -.60     208                                41.78
  573 29252 00000      1638   10

2?028    345 401 18 130053.54    .00    0 -.00       0                .0      .0  13.77
      29242 00000         0 117

3 028    345 401 18 130053.54                                                           752.9      1105.0  39.4 149.0
      29242 00000                                                                       46.7 179.2      8 25

5?081    029 401 18 054452.18    .00   37-3.28    7359              23.2    78.9   6.40
      29204  00000        0 146

6 081    029 401 18 054452.18
      29204  00000                                                                                           -3.3 269.7
```

4.2.1.3.2 SRCHEK

Normally the SRTMRG and SRCHEK programs are automatically run immediately after RASSN, so the SRCHEK output is included here. The quantities printed are:

1. Satellite number and name.
2. Epoch date and time (year, month, day, hour, minutes, seconds, thousandths of seconds).
3. Element number.
4. RMS value and RMS limit.
5. Delta T and mean delta T (of Ra's in last 5 days).
6. Number of observations from date and time, to date and time
7. Predicted date and time at which delta T will reach or exceed .8 minutes (.8 DELTA T). A minus sign after the date indicates that the satellite will not reach .8 minutes prior to bulletin expiration. A plus sign indicates that the satellite will exceed .8 minutes before the elements expire. Eleven X's will be printed for satellites with less than 5 observations or when the slope of the least square fit is zero.
8. Number of blocks on the SRADU tape being utilized for observations on the satellite and where they are located.
9. Number of Ra's since epoch and in the last two days.

4.2.1.3.3 SATTB from SRCHEK

A Satellite Table (SATTB) is also produced by the SRCHEK program. This table contains those satellites which require an SGPDC run. Specific information for each satellite is printed:

1. Indicators, listed in order of priority
   a. Minus (-) - bulletin/element expiration date is within 36 hours of expiration.
   b. Plus (+) - RMS exceeds RMS limit for the satellite.
   c. Plus L (+L) - No Ra's within the last two days.
   d. Plus T (+T) - Mean Δt of all Ra's for last five days exceeds .4 minutes.
   e. I suffix - an automatic run has been generated.

2. RMS value
3. Number of observations
4. Delta T

SAMPLE PRINTOUT, SRCHEK SATTB

SATTB- LIST OF SATELLITES WHICH NEED ELEMENTS CORRECTED

SATELLITE NO.		RMS	NO. OF OBS.	T - TO
+L	059	24	5	12.2
-I	081	8	2	.9
+L	188	0	0	6.7
+L	194	38	6	29.2
+L	195	6	1	18.2
+L	196	15	2	26.1
+L	205	0	0	4.0
+L	239	0	0	13.9
+L	273	26	4	17.0
+L	322	96	12	9.4
+L	359	0	0	.8
+T	378	179	22	39.1

4.2.1.3.4 Analyst RASSN

If a parameter card is used in input with input options 5 or 6 (Analyst RASSN) the RASSN output will be presented in a slightly different format although the content is the same. All of the associations within the limits specified will be printed in the doubtful format to allow printing of all residuals. The last line for each observation will be in the unassociated format to allow printing of the observational data.

SAMPLE PRINTOUT, SRCHEK

```
SATELLIT 780    1964-170                      EPOCH 64-04-15-04-17-35.044   ELEMENTS        4
                         RMS=    .10401843+3   RMS LIMIT=    .18354164+3        DELTAT =      .297   MEAN      .176
        23 OBSERVATIONS, FROM 64-04-15-04-43-12.354 TO 64-04-17-08-58-33.482        .8 DELTA T     64-04-21-19 -
         2 BLOCKS, FROM    4414 TO    4415                         19 RA'S     19 RA'S IN LAST TWO DAYS

SATELLITE  782 NOT IN EFILE
                         RMS=    .10401843+3   RMS LIMIT=    .18354164+3        DELTAT =      .000   MEAN
        61 OBSERVATIONS, FROM 64-04-09-18-48-20.782 TO 64-04-10-10-52-59.992        .8 DELTA T     XXXXXXXXXXX -
         6 BLOCKS, FROM    4416 TO    4421                         51 RA'S      0 RA'S IN LAST TWO DAYS

SATELLIT 783    1964-190                      EPOCH 64-04-14-01-09-20.721   ELEMENTS        3
                         RMS=    .10336813+3   RMS LIMIT=    .18596797+3        DELTAT =      .434   MEAN      .125
        59 OBSERVATIONS, FROM 64-04-12-09-47-58.864 TO 64-04-17-04-28-04.240        .8 DELTA T     64-04-19-14 -
         5 BLOCKS, FROM    4422 TO    4426                         38 RA'S     10 RA'S IN LAST TWO DAYS
```

SAMPLE PRINTOUT, ANALYST RASSN

```
                                                                                                      PAGE    1
S
T OSAT STAT YMM DD HHMMSS.SS      DT      U   BETA VEC-MAG    DRANG    DELEV DACOSH  TT-TO      ALT       RANGE  ELEV   AZIM
A                                 MIN    DEG   DEG    KM       KM       DEG    DEG    DAYS      KM         KM     DEG    DEG
T NSAT OBSN  MSGNO      REV   EL                              DELH     DELTA                    LAT   LONG  SID.T  RRAT    DRR
U                                                                                               DEG   DEG   HH MM   M/S    M/S
S

2  709  216 312 28 180018.95     .63 118   .14    333        42.1     4.3   44.6   2.09
   709 40924 00000     237    7                              90.8     .37

3  709  216 312 28 180018.95                                                               355.7    405.1   60.5 345.7
        40924 00000                                             .0     .00                 41.6 284.5 19 26

********
2  709  216 312 28 180009.00     .60 118   .09    382        67.1    -9.6  -52.0   2.09
   709 40923 00000     237    7                              26.0     .27

3  709  216 312 28 180009.00                                                               332.2    407.6   53.8 334.8
        40923 00000                                             .0     .00                 41.8 283.9 19 26

********
2  709  216 312 28 175958.99     .59 117   .06    399       105.8   -20.3   44.1   2.09
   709 40922 00000     237    7                              17.0     .18

3  709  216 312 28 175958.99                                                               324.3    438.2   46.4 326.6
        40922 00000                                             .0     .00                 42.1 285.1 19 26
```

4.2.2 OBSERVATION SEPARATION - OBSSEP

4.2.2.1 Purpose

The OBSSEP program separates the observations on a R-tape into two groups, generating two new R-tapes. The separation is based on observation time. Those observations falling within the specified time slice(s) will be placed on a "high priority" R-tape, and all others on a "low priority" R-tape.

4.2.2.2 Input

Each time slice is specified by the analyst and input via the flexowriter:

a. Hour, minute, month, day and year of start time.

b. Hour, minute, month, day and year of stop time.

4.2.2.3 Output

No program printout is generated by this program.

4.2.3 NODAL CROSSING REDUCTION - REDUCT

4.2.3.1 Purpose

The REDUCT program reduces observations to the last nodal crossing, computes residual differences between the observations and an element set and compares the differences against specified tolerance limits. There are three sub-sections in the REDUCT program.

a. General - for visual, radar and/or Baker-Nunn observations

b. Doppler - for doppler observations

c. Direction Finder - for direction finder observations

Residuals Computed by Various Program Sections

Program Section	Time Residual	Right Ascension Residual	Height Residual
Visual	X	X	X
Radar	X	X	
Baker-Nunn	X	X	
Doppler	X		
Direction Finder	X		

Tolerance Codes and Corresponding Values

Code	Time (days)	Right Ascension (degrees)	Height (km)
Blank } 0	.002	20	200
1	1	5	500
2	.003	360	10000
3	.002	360	10000
4	.001	360	10000
5	.003	5	300
6	.05	2.5	200

4.2.3.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-30	REDUCT
		31-35	,DATA
5	Parameter Card		
		1	0 = Special sensor tape (not the S-file tape) input
			1 = Sensor cards input
		3	0 = Use interim tape and check residuals vs. tolerance limits
			1 = No interim tape and no check of residuals vs. tolerance limits
		8	0 = Identified observations processed against associated element set only
			1 = All observations processed as unknowns
		9	0 = Hardcopy output
			1 = Hardcopy and TTY output
		10	0 = Re-reduction, with open tolerance limits, of unassociated observations
			1 = No re-reduction of unassociated observations
		11	0 = Compute perigee distance
			1 = Use perigee distance from element set
6	Element Lead Card		
		8	7 = Card type
7	Element Set Cards (max. = 25 sets)		
8	Sensor Lead Card (unnecessary with special sensor tape)		
		8	8 = Card type

Deck Position	Card Type	Column Number	Punch
9	Sensor Cards (max. = 750 sensors)		
10	Observation Lead Card		
		7	0 (or Blank) = Tolerance Code 0
			1 = Tolerance Code 1
			2 = Tolerance Code 2
			3 = Tolerance Code 3
			4 = Tolerance Code 4
			5 = Tolerance Code 5
			6 = Tolerance Code 6
		8	8 = Card Type

NOTE: The tolerance limits for a group of observations may be changed by preceding the observation cards with another Observation Lead card.

Deck Position	Card Type	Column Number	Punch
11	Observation Cards (no limit)		
12	Blank Card		
13	End of Input Card		
		79	9 = Card type
14	End of Data Card		
15	End of Job Card		
16	End of Schedule Tape Card		
17	Blank Card		

4.2.3.3 Output

4.2.3.3.1 Satellite Inventory

Output begins with the satellite inventory. Seven groups, composed of satellite number and element number, are printed per line.

4.2.3.3.2 Observation Output

Observation output will occur in three formats depending on which part of the program has done the reduction.

4.2.3.3.2.1 General Reduction Output

1. Observation identification number
    a. Satellite number
    b. last digit of year of observation
    c. month, day, hour, minutes, seconds, hundredths of seconds (ID)
2. Epoch revolution number (N)
3. Argument of latitude (U)
4. Time of nodal crossing (T sub N)
5. Time residual in days (DELTA T)
6. Latitude of subsatellite point (PHI S)
7. Longitude of subsatellite point (LS)
8. Right ascension of ascending node in degrees (RA N)
9. Right ascension residual (DEL RA)
10. Height in kilometers (H (KM))
11. Height residual (DEL H) - zero for B-N or VIS.
12. Obs type (TYPE) - VIS for visual
RDR for radar
B-N for Baker-Nunn
13. Element Number (ELEM)
14. Station number (STA)
15. Optional $ - implies observation time precedes epoch by more than 4 days.

4.2.3.3.2.2 Direction Finder Reduction (not currently used)

1. Identification (same as for general reduction)
2. Epoch revolution (N)
3. Time of nodal crossing (T SUB N)
4. Time residual (DELTA T)
5. Elevation in degrees (H)
6. Slant range in kilometers (S)
7. Height in kilometers (H (KM))
8. Element number (ELEM)
9. Station number (STA)

4.2.3.3.2.3 Doppler Output (not currently used)

1. Identification (same as for general reduction)
2. Epoch revolution (N)
3. Computed time of nodal crossing (T SUB N)
4. Time residual (DELTA T)
5. Arc distance in nautical miles from station to subsatellite point (D)
6. Elevation in degrees (H)
7. Slant range in kilometers (S)
8. Element number (ELEM)
9. Station number (STA)

4.2.3.3.3 Explanatory Comments

Miscellaneous informative comments may be interspersed for observations. These always appear with the ID information. Some of the more significant comments are:

1. UNTAGGED UOS REDUCED W/O TOLERANCES

   All observations which follow have previously appeared as untagged UO's, and have now been re-reduced with large tolerances.

2. UO S FOLLOW

   All observations which follow on the page did not correspond to any satellite whose elements are stored in the catalog.

3. UNK***********

The next observation is an unknown. The message number is given. If the observation was a known observation which was treated as an unknown, the satellite number is also given.

SAMPLE PRINTOUT, REDUCT

```
SATELLITE INVENTORY FOLLOWS.*
881 137/ 831  98/ 341  20/ 444  68/ 455   4/

 UO 8 FOLLOWS
UNK************
                            00000    *
                                             081
                   ID        N      U       T SUB N  DELTA T      PHI S      L 8      RA N  DEL RA      H(KM)      OPL M TYPE ELEM   STA
 88131112 11344892 12248  43.76 316.47137920 -0.01091  25.770  259.86   47.74    0.94   2284.0      0.0  8=N 127.    33
UNK************
                            00000    *
                                             081
 08131112 09411844 12244  43.11 316.39271110 -0.01133  25.441  288.49   88.74    1.42   8222.1      0.0  8=N 127.    33
 44431112 09411244   3810 148.89 316.35414920 -0.01277  29.882  874.03  301.06   -0.09    816.6      0.0  8=N  60.    38
UNK************
                            00000    *
                                             081
 08131112 00322059 12244  19.83 316.39268890 -0.01135  12.312  269.40   87.09    0.77   1917.2      0.0  8=N 127.    33
UNK************
                            00000    *
                                             081
 08131111 10045800 12236 121.99 315.70264578 -0.01552  32.800  241.85   49.92   -0.13   1003.6     30.0  RD* 127.   745
UNK************
                            00000    *
                                             081
 08131111 17104008 12238 110.83 315.68390280 -0.01804  33.009  288.42   80.94   -0.80   1920.4     31.5  RD4 127.   740
UNK************
                            00000    *
                                             081
 08131110 18100078 12280  36.42 314.90229820 -0.02486  20.004  849.73   84.64   -0.85   2220.7      0.0  V28 127.   695
UNK************
                            00000    *
                                             081
 00031100 10581920      UNTAGGED UO.          35        0.00*
UNK************
                            00000    *
                                             081
 08131100 10571296 12206 253.36 313.39827460 -0.03335 -37.037  137.65  100.86    1.96    438.5      0.0  8=N 127.    358
 88131100 10571096 12088 222.27 313.41509060  0.00231 -38.811  137.04  150.39   -0.84    939.4      0.0  8=N  79.    35
 85531100 10571296 11168 229.08 313.40833410  0.00329 -44.801  138.88  147.10    1.11   1157.6      0.0  8=N   4.    35
UNK************
                                   *
                                             444
 44431110 13052408  3800  56.42 314.52110090 -0.00004  52.190   83.24  303.05   -0.18   4263.1    -30.7  ROR  69.   326
UNK************
                            00000    *
                                             444
 00031113 18293400  STATION  316 NO STORED COORDINATES(2).
                                                                 316*
 00031112 18226400      UNTAGGED UO.         318        0.00*
```

4.2.4 OTHER

The following programs in the Association area are seldom used by the analyst. A brief description of each program is given.

4.2.4.1 GOODER

The GOODER program is used when the SRCHEK program indicates that there are satellites out of order on the SRADU tape. The program generates a new SRADU tape restoring the satellites to their proper order.

4.2.4.2 MAP

MAP is a program designed to assemble DMNI data into input observation messages in a format acceptable to ORCCN. The DMNI input tapes are generated in real-time by INTPROC or off-line with the 410 Recorder. The DMNI tapes currently contain only the high-speed data from BMEWS; however, the MAP program is designed to process both high-speed and teletype data. The only data currently assembled by MAP are BMEWS Q-point (penetrations of the BMEWS fans) messages. All other data, including incomplete messages and improper formatted messages, is discarded.

The DMN1 dump tapes are processed in the order in which they were generated. A left-over message table is maintained by MAP to prevent loss of data between successive DMNI tapes.

4.2.4.3 OBSEND

The OBSEND program produces teletype and/or hard copy outputs from observations on the SRADU tape. The program is used for transmitting observations to the backup facility at Hanscom. The program allows for outputing selected satellite observations or all observations on the SRADU tape.

4.2.4.4 OPURGE

The OPURGE program is used to purge observations from the SRADU tape. The program operates in four modes as follows.

a. Mode one - delete all observations for a specific satellite.

b. Mode two - delete only those observations requested by satellite and sensor number.
c. Mode three - delete individual observations as specified by satellite and observation number
d. Mode four - delete all observations prior to an input time and satellite number.

4.2.4.5 ORCON

The purpose of ORCON is to decode, edit, and store sensor observations. The observation reports are in a variety of formats and may be received via teletype, or digital data link (BMEWS). All observations of various types received via the several communications systems are converted to one standard format and stored on an R-tape. Error checking is performed and observations in error are not stored on the R-tape; however, they are recorded on the system output tape so corrective action can be taken.

4.2.4.6 PRINTER

The PRINTER program is an observation editing program. It converts the observations on the R-tape to a readable format. The program is presently used after the operation of ORCON to determine if all input data (especially BMEWS Q-point messages) has been converted. The program will also convert the information on the DMNI dump tapes to a readable format. This option is especially useful in the checkout of certain programs and in error correction

4.2.4.7 RTPJUG

The function of the RTPJUG program is to transfer all unprocessed observations from the R-tape to a scratch tape so they can be processed later by RASSN. The console interrupt mode would be used only if a high priority run is required during the operation of RASSN.

RTPJUG is run as a result of

a. A console interrupt during the operation of RASSN, or
b. As a manual program when a machine malfunction occurs during the operation of RASSN

4.2.4.8 RUMOV

The RUMOV program transfers the unassociated observations from the SRADU tape to an R-tape for reprocessing by RASSN.

4.2.4.9 SRADU

The SRADU program generates a SRADU tape from standard observation cards. The program first builds a RADU tape and then calls in the SRTMRG program which sorts the RADU tape and builds the SRADU tape.

4.2.4.10 SRCHEK

The SRCHEK program is normally run automatically after SRTMRG in the association sequence. However, the program can be run in the manual mode. The program is used to:

a. determine if errors exist on the SRADU tape
b. furnish a satellite table (SATTB) of those satellites whose elements need updating
c. describe the observational status of each satellite on the SRADU tape (e.g., RMS, mean Δt, number of Ra's received in last five days, etc.)

4.2.4.11 SRTMRG

The SRTMRG program is normally run automatically after the operation of RASSN. However, it can be run as a manual program if tape errors are encountered. Its main functions are to:

a. Sort all newly associated observations (stored on RADU tapes) and merge these observations onto the system observation tape (SRADU tape.)
b. Produce observation cards from the newly associated observations. These cards are used for running programs in the schedule tape mode and for system backup files.
c. Purge those observations from SRADU tape that are not useful in the differential correction function.

4.3 ELEMENT DETERMINATION AREA

The Element Determination area includes the initial orbit computation programs (IOHG, IORF, IOANGLE, and ROC), the differential correction programs (SGPDC, SPWDC and ESPOD), the maintenance and summary programs (SUM, SEAI, HANSEL, MSGV, LOCVEC, XROADS and CCOE), and the decay prediction program (SPIRDECB).

4.3.1 ELECTRONIC SYSTEMS PRECISION ORBIT DETERMINATION - ESPOD [1]

4.3.1.1 Purpose

The ESPOD program differentially corrects a given element set (first updating the elements to a later epoch on option) and computes predicted satellite positions. It can further differentially correct a given set of constant biases in range, azimuth/right ascension, elevation/declination, range rate, sensor longitude, sensor latitude, sensor height, and time for several sensors. The differential correction is accomplished using a weighted least squares fit to the observations. The trajectory and ephemeris computations use a special perturbations Cowell formulation, where the whole force field is integrated. The (optional) update of the elements to a later epoch uses a simplified general perturbations formulation. Various statistical quantities are calculated and output to aid the analyst in determining the degree of validity of the results. ESPOD may be used for orbits of any eccentricity (including elliptic, parabolic, and hyperbolic types) provided the earth is the primary force center. Perturbations due to the moon and sun are accounted for by using ephemeris tapes of these bodies. Several atmospheres are available on option.

4.3.1.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		

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1. The write-up for the ESPOD program input has been furnished by the 496L SPO.

Deck Position	Card Type	Column Number	Punch
3	Remarks Card (optional)		
4	Program ID Card		
		17-19	RUN
		25-29	ESPOD
		30-34	,DATA
5	Job Description Card		
		1-3	JDC = Card type
		4-7	Satellite Number (rt. adj.)
		8-17	Satellite Name (optional)
		18-29	Header to be printed on output (optional)
		30	0 = COLD START
			1 = CONDITIONED START (i.e. results generated on Tape 7 by previous ESPOD runs are input on Tape 7.
			2 = CONDITIONAL START
		31	0 = Neither observations nor sensors are input in any way except by a previous Tape 7.
			1 = Either observations and/or sensors are input in the deck or on SRADU or SEAI tapes.
		32	0 = Do not print sensor locations.
			1 = Print sensor locations.
		33	0 = Do not print observations.
			1 = Print observations.
		34	0 = No sensor cards are in input deck.

Deck Position	Card Type	Column Number	Punch
		34	1 = Sensor cards are in input deck (These will supplement or override sensor data from SEAI tape).
		35	0 = Obtain observations from SRADU tape.
			1 = Obtain observations from observation cards in input deck.
		36	0 = Do not print the constants used in ESPOD.
			1 = Print the constants used in ESPOD.
		37	0 = Use seven-card element set from input deck or E-file, or use ICTYP card in input deck, or previous Tape 7.
			1 = Use elements stored by a PRDCT card on an immediately preceding ESPOD run.
		41	0 = Do not differentially correct.
			1 = Differentially correct (i.e. use ESPODDC).
		42	0 = A-priori A^TA matrix not input.
			1 = A-priori A^TA matrix input (SMAT cards).
		43	0 = Do not punch $(A^TA)^{-1}$ matrix.
			1 = Punch $(A^TA)^{-1}$ matrix each iteration. (UPMAT cards)
		44	0 = Do not punch A^TA matrix.
			1 = Punch A^TA matrix each iteration (SMAT cards)

Deck Position	Card Type	Column Number	Punch
		45	0 = Print the u, v, w residuals.
			1 = Print the s, t, w residuals.
			2 = Print sensor latitude, longitude, height residuals (i.e. how much sensor must be "moved" to make calculated orbit coincide with observation)
		46	0 = Retain "proven" elements for use in the calculation of the predictions. ("Proven" elements are those which were used to calculate the trajectory and residuals of the very last iteration).
			1 = Retain "new" elements for use in the calculation of the predictions ("new" elements are those which were predicted by the very last iteration, but which have not been used for the calculation of residuals).
		47	0 = Normal differential correction on same elements each iteration.
			1 = Calculate velocity correction to minimize the RMS of the time residuals, but do not apply the correction.
			2 = Calculate velocity correction to minimize the RMS of the time residuals, and apply the correction on first iteration.

Deck Position	Card Type	Column Number	Punch
		51	0 = Do not calculate predictions or epnemeris.
			1 = Calculate predictions/ephemeris (i.e., use ESPODEPH)
		52	0 = DAC cards are not present in input deck.
			1 = DAC cards are present in input deck.
		53	0 = Do not generate an XYZ ephemeris tape.
			1 = Generate an XYZ ephemeris tape on Tape 10 for the program XYZLA, writing all ephemeris points on output Tape 11 as well.
			2 = Generate an XYZ ephemeris tape on Tape 10 for the program XYZLA, writing only first and last ephemeris points on output Tape 11.
		55	0 = Do not output the updated statistical quantities.
			1 = Output the updated statistical quantities (i.e. those associated with the points of the ephemeris).
		56	0 = Do not punch the updated covariance matrix inverse ($A^T A$ matrix, SMAT cards).
			1 = Punch the updated covariance matrix inverse.

NOTE: Zeros and blanks are equivalent for Cols. 30-80.

NOTE: All cards between the JDC and ENDPR cards may be in any order.

Deck Position	Card Type	Column Number	Punch
	Remarks Card (optional)		
		1-2	01 = Card number.
		5-7	REM
		10-72	(As desired). These remarks are printed on the ESPOD output, but are not typed on the flexowriter.
	Initial Conditions Card #1 (omitted if seven-card element set is in the input deck or is obtained from the SEAI tape).		
		1-2	01 = Card number.
		3-4	Differential Correction Iteration Number (optional)
		5-9	ICOND = Card type.
		10-23 *	Initial value of Right Ascension (deg) (or longitude east (deg)) or X (km).
		29-42 *	Initial value of Declination (deg) or Y (km).
		48-61 *	Initial value of Flight Path Angle (deg) or Z (km).
		67-80 *	Initial value of Azimuth of Velocity Vector (deg) or $\dot{X}$ (km/sec).
	Initial Conditions Card #2 (omitted if seven-card element set is in the input deck or is obtained from the SEAI tape).		
		1-2	02 = Card number.
		3-4	Differential Correction Iteration Number (optional).

NOTE: Asterisk means use decimal point somewhere in field.

Deck Position	Card Type	Column Number	Punch
		5-9	ICOND = Card type.
		10-23 *	Initial value of geocentric range (km) or $\dot{Y}$ (km/sec).
		29-42 *	Initial value of magnitude of velocity vector (km/sec) or $\dot{Z}$ (km/sec).
	Initial Time Card #1		(omitted if seven-card element set is in the input deck or is obtained from the SEAI tape).
	(This card gives the time associated with Initial Conditions, i.e. epoch).		
		1-2	01 = Card number.
		5-9	ITIME = Card type.
		10-23 *	Last two digits of year plus decimal point.
		29-42 *	Month of year (one or two digits plus decimal point).
		48-61 *	Day of month (one or two digits plus decimal point).
		67-80 *	Hour of day (one or two digits plus decimal point).
	Initial Time Card #2		(omitted if seven-card element set is in the deck or is obtained from the SEAI tape).
		1-2	02 = Card number.
		5-9	ITIME = Card type.

NOTE: Asterisk means use decimal point somewhere in this field.

Deck Position	Card Type	Column Number	Punch
		10-23 *	Minutes of hour (one or two digits plus decimal point).
		29-42 *	Seconds of minute (one or two digits plus decimal point plus decimal fraction of second).
	Initial Conditions Type Card (omitted if seven-card element set is in input deck or is to be obtained from SEAI tape.)		
		1-2	01 = Card number.
		5-9	ICTYP = Card type.
		10-23 *	1.0 = Initial Conditions are right ascension, declination, flight path angle, azimuth of velocity vector, magnitude of geocentric range, magnitude of velocity vector. (i.e. ADBARV).
			2.0 = Initial Conditions are: east longitude, declination, flight path angle, azimuth of velocity vector, magnitude of geocentric range, magnitude of velocity vector. (i.e. λ DBARV)
			3.0 = Initial conditions are $XYZ\dot{X}\dot{Y}\dot{Z}$
12	Drag Parameter Card		(Can be omitted if drag is negligible. Must be input if DC is on Cd A/2M).

NOTE: Asterisk means use decimal point somewhere in this field.

Deck Position	Card Type	Column Number	Punch
		1-2	01 = Card number.
		3-4	Differential correction iteration number (optional).
		5-8	DRAG.
		10-23 *	Initial value of Cd A/2M (in square meters/ kilogram) where Cd = Coefficient of Drag (approx. 2.2) A = Cross-sectional area of satellite. M = Mass of satellite.
		29-42 *	Initial value of K.
		48-61 *	Blank or 0.0 = No drag variation 1.0 = Drag variation model is $K\ (\frac{1}{2}\cos^5 \frac{\varphi}{2} - \frac{1}{4})$ (day-night) 2.0 = Drag variation model is $K\ (\frac{t-to}{1440})$ (secular)
		67-80 *	1.0 = Use ARDC 1959 Static Atmosphere 2.0 = Use Paetzold/ARDC 1959 Dynamic Atmosphere Blank or 0.0 or 3.0 = Use COESA 1962 Static Atmosphere 4.0 = Use COESA 1962 Dynamic Atmosphere.

NOTE: An asterisk means use decimal point somewhere in this field.

NOTE: APF 10 cards must be input if a dynamic atmosphere is used.

Deck Position	Card Type	Column Number	Punch

NOTE: Trailing floating point fields may be left blank, but no in-between floating-point fields may be left blank (fill with 0.0 if not used).

13	Bounds Parameter Card(s)		(These cards input if and only if one wishes to override the nominal values of bounds which are built into ESPOD). (The bounds appear in one-to-one correspondence and order as the one-punch flags on the CAT1 and CAT2 cards).
		1-2	Bounds Card Number (e.g. 01, 02, 03, etc.)
		3-4	Differential Correction Iteration Number (optional)
		5-8	BNDS = Card type.
		10-23 *	Maximum value of change between iterations of a differential correction variable (i.e. initial condition, drag, drag variation, or bias).
		29-42 *	(Same as cols. 10-23 but for another variable).
		48-61 *	(Same as cols. 10-23 but for still another variable).
		67-80 *	(Same as cols. 10-23 but for still another variable).

NOTE: Asterisk means use decimal point somewhere in this field.

Deck Position	Card Type	Column Number	Punch

NOTE: As many BNDS cards may be used as are necessary to specify the required number of bounds. The last BNDS card may have several trailing blank fields. For example, only one bound might appear on the last BNDS card.

NOTE: Units of the bounds are the same as the units of the variables corresponding to the bounds.

Category One Differential Correction Variables Card

NOTE: If a differential correction is to be performed (i.e. col. 41 of JDC card has one punch) and if both CAT1 and CAT2 cards are omitted, ESPOD automatically differentially corrects the six ADBARV variables. If a differential correction is to be performed only on Category 2 variables (biases), or if no differential correction is to be performed at all (i.e. col. 41 of JDC card is blank or zero), then omit CAT1 card.

		1-2	01 = Card number.
		5-8	CAT1 = Card type.
		10	0 = Do not differentially correct Alpha (Right Ascension).
			1 = Differentially correct Alpha (Right Ascension.
		11	0 = Do not differentially correct Delta (Declination).
			1 = Differentially correct Delta (Declination).

Deck Position	Card Type	Column Number	Punch
		12	0 = Do not differentially correct Beta (Flight Path Angle).
			1 = Differentially Correct Beta (Flight Path Angle).
		13	0 = Do not differentially correct Az (Azimuth of Velocity Vector).
			1 = Differentially correct Az (Azimuth of Velocity Vector).
		14	0 = Do not differentially correct R (Magnitude of geocentric range vector).
			1 = Differentially correct R (Magnitude of geocentric range vector).
		15	0 = Do not differentially correct V (Magnitude of velocity vector).
			1 = Differentially correct V (Magnitude of velocity vector).
		16	0 = Do not differentially correct Cd A/2M.
			1 = Differentially correct Cd A/2M.
		17	0 = Do not differentially correct K (Drag variation parameter).
			1 = Differentially correct K (Drag variation parameter).

Deck Position	Card Type	Column Number	Punch
	Number of DC Iterations Card (If this card is omitted, ESPOD assumes a maximum of five DC iterations).		
		1-2	01 = Card number.
		5-9	NITER = Card type.
		10-23 *	Maximum number of differential correction iterations (integral number plus decimal point).
	Weighting Parameter Card(s) (Input if and only if one wishes to supplement or override the weighting parameters which are already built into ESPOD).		
		1-2	Sigma Type Number (in the Master Sigma or Sensor Type List, or as associated by an STYPE card). (Number may range between 01 and 60).
		5-9	SIGMA = Card type.
		10-23 *	Standard Deviation in Range (km) (Right Ascension of Field Reduced BN) expected for sensor(s) associated with the Sigma Type Number.
		29-42 *	Standard Deviation in Azimuth (degrees) (Declination of Field Reduced BN) expected for the sensor(s) associated with the Sigma Type Number.

NOTE: Asterisk means this field must have decimal point somewhere in it.

Deck Position	Card Type	Column Number	Punch
		48-61 *	Standard Deviation in Elevation (degrees) (Right Ascension of Precision Reduced BN) expected for the sensor(s) associated with the Sigma Type Number.
		67-80 *	Standard Deviation in Range Rate (km/sec) (Declination of Precision Reduced BN) expected for the sensor(s) associated with the Sigma Type Number.
	Sensor Type and Parameter Card(s)		
			(Input if and only if one wishes to supplement or override the sensor weighting types and parameters which are already built into ESPOD).
		1-2	Sensor Type and Parameter Card Number (e.g. 01, 02, 03,...)
		5-9	STYPE = Card type.
		10-13	Sensor Number.
		14-15	Sigma Type (i.e. weighting type) to be associated with the sensor in columns 10-13. (Two digits, no decimal).
		16-19	Gross Outlier Rejection parameter (Gs) for the sensor in columns 10-13. (Right adjusted, no decimal point).

NOTE: Asterisk denotes use of decimal point somewhere in this field.

Deck Position	Card Type	Column Number	Punch
		20	0 or blank = Do not apply refraction correction to measurements of sensor in columns 10-13. 1 = Apply refraction correction to sensor in col. 10-13.
		21-23	N_s (mean surface value of refractivity $\cdot 10^6$) for the sensor in columns 10-13, (not required if col. 20 is blank).
		29-32	Sensor Number.
		33-34	Sigma Type (i.e. Weighting Type) to be associated with sensor in col. 29-32 (two digits, no decimal).
		35-38	Gross Outlier Rejection parameter (Gs) for the sensor in col. 29-32 (right adjusted, no decimal point).
		39	0 or blank = Do not apply refraction correction to measurements of sensor in col. 29-32. 1 = Apply refraction correction for sensor in col. 29-32.
		40-42	N_s (mean surface value of refractivity $\cdot 10^6$) for the sensor in columns 29-32; (not necessary if col. 39 is blank).
		48-51	Sensor Number
		52-53	Sigma Type (i.e. Weighting Type) to be associ-

Deck Position	Card Type	Column Number	Punch
			ated with the sensor in col. 48-51 (two digits, no decimal).
		54-57	Gross Outlier Rejection parameter (Gs) for the sensor in col. 48-51 (right adjusted, no decimal).
		58	0 or blank = Do not apply refraction correction to measurements of sensor in col. 48-51. 1 = Apply refraction correction for sensor in col. 48-51.
		59-61	N_s (Mean Surface Refractivity $\cdot$ 10^6) for sensor in cols. 48-51. (Not required if col. 58 is blank).
		67-70	Sensor Number.
		71-72	Sigma Type (i.e. Weighting Type) to be associated with the sensor in col. 67-70 (two digits, no decimal).
		73-76	Gross Outlier Rejection parameter (Gs) for the sensor in col. 67-70 (right adjusted, no decimal).
		77	0 or blank = Do not apply refraction correction to measurements of sensor in col. 67-70. 1 = Apply refraction correction for sensor in col. 67-70.
		78-80	Ns (Mean Surface Refractivity $\cdot$ 10^6) for sensor in cols. 67-70. (Not required if col. 77 is blank).

Deck Position	Card Type	Column Number	Punch

NOTE: Only those fields which one wishes to supplement or override need to be input. The Gross Outlier Rejection parameter causes observations to be rejected as follows:

Reject Range Observation if $|\text{Range Residual}| > G_s$ (standard deviation in range for this sensor).

Reject Azimuth Observation if $|(\text{Azimuth Residual}) \cos \text{Elevation}| > G_s$ (standard deviation in Azimuth for this sensor)

Reject Elevation Observation if $|\text{Elevation residual}| > G_s$ (standard deviation in Elevation for this sensor).

Reject Range Rate Observation if $|\text{Range Rate Residual}| > G_s$ (standard deviation in range rate for this sensor).

Reject Right Ascension Observation if $|(\text{Right Ascension Residual}) \cos \delta| > G_s$ (standard deviation in right ascension for this sensor).

Reject Declination Observation if $|(\text{Declination Residual})| > G_s$ (standard deviation in declination for this sensor).

Category Two Differential Correction Variables Card(s) (Biases) (Omitted if no DC to be done on Category Two Variables).

Column Number	Punch
1-2	Category Two Card Number (e.g. 01, 02, 03,etc.)
5-8	CAT2
10-13	Sensor Number
14	0 = Do not differentially correct RANGE BIAS for this sensor.

Deck Position	Card Type	Column Number	Punch
			1 = Differentially correct RANGE BIAS for this sensor.
		15	0 = Do not differentially correct AZIMUTH BIAS for this sensor.
			1 = Differentially correct AZIMUTH BIAS for this sensor.
		16	0 = Do not differentially correct ELEVATION BIAS for this sensor.
			1 = Differentially correct ELEVATION BIAS for this sensor.
		17	0 = Do not differentially correct RANGE RATE BIAS for this sensor.
			1 = Differentially correct RANGE RATE BIAS for this sensor.
		18	0 = Do not differentially correct RIGHT ASCENSION BIAS for this sensor.
			1 = Differentially correct RIGHT ASCENSION BIAS for this sensor. (Must be optical sensor).
		19	0 = Do not differentially correct DECLINATION BIAS for this sensor.
			1 = Differentially correct DECLINATION BIAS for this sensor. (Must be optical sensor).

Deck Position	Card Type	Column Number	Punch
		20	0 = Do not differentially correct TIME BIAS for this sensor.
			1 = Differentially correct TIME BIAS for this sensor.
		21	0 = Do not differentially correct this sensor's LATITUDE BIAS.
			1 = Differentially correct this sensor's LATITUDE BIAS.
		22	0 = Do not differentially correct this sensor's LONGITUDE BIAS.
			1 = Differentially correct this sensor's LONGITUDE BIAS.
		23	0 = Do not differentially correct this sensor's HEIGHT BIAS.
			1 = Differentially correct this sensor's HEIGHT BIAS.
		29-32	Sensor Number.
		33-42	Information identical with Column Numbers 14 through 23.
		48-51	Sensor Number.
		52-61	Information identical with Column Numbers 14 through 23.
		67-70	Sensor Number.

Deck Position	Card Type	Column Number	Punch
		71-80	Information identical with Column Numbers 14-23.

NOTE: Any number of CAT2 cards may be used. However, only the last CAT2 card may have trailing blank fields. That is, there must be four sensors per CAT2 card except for the last CAT2 card, which may have any number between one and four).

Bias Estimate Card(s) (Initial Value of Biases). (Omitted if no differential correction is being performed on any Category Two Variables (Biases). If a D.C. is being done on any biases, ESPOD will automatically make initial bias estimates of zero if this card is omitted).

		1-2	Bias Estimate Card Number (e.g. 01, 02, 03, etc.)
		3-4	Differential Correction Iteration Number (optional).
		5-9	BISES = Card Type.
		10-23 *	Initial value of a bias.
		29-42 *	Initial value of another bias.
		48-61 *	Initial value of still another bias.
		67-80 *	Initial value of still another bias.

NOTE: Asterisk means use decimal point somewhere in this field.

NOTE: Any number of BISES cards may be used. However, only the last BISES card may have trailing blank fields. That is, there must be four bias initial values per BISES card except for the last BISES card, which may have any number between one and four. The initial values

Deck Position	Card Type	Column Number	Punch

of the biases should be listed in one-to-one correspondence and order as the one-punch flags on the CAT2 card(s).

20 S-matrix Card(s) (a-priori A^TA matrix) (optional input)

		1-2	S-matrix card number (e.g. 01, 02, 03...)
		3-4	Differential Correction Iteration Number (optional).
		5-8	SMAT = Card type.
		10-23 *	Value of an element of the S-matrix.
		29-42 *	Value of an element of the S-matrix.
		48-61 *	Value of an element of the S-matrix.
		67-80 *	Value of an element of the S-matrix.

NOTE: An asterisk indicates a floating point field.

NOTE: As many S-matrix cards (sequentially numbered) as are necessary to completely give the matrix are input. As the matrix is symmetric, only the upper triangular elements are input. They are input in the following order: the top row from left to right, the second row from left to right beginning at the second element, the third row from left to right beginning at the third element, etc.

NOTE: If the S-matrix is input, col. 42 of the JDC card must have a one-punch.

NOTE: If the JDC card has a one-punch in col. 44, S-matrix cards corresponding to epoch will be punched out in the correct format after each

Deck Position	Card Type	Column Number	Punch

iteration. If the JDC card has a 1 in col. 56, S-matrix cards corresponding to each ephemeris point will be punched.

NOTE: If S-matrix cards are input, then CAT1 and CAT2 cards(punched to indicate the respective variables of the SMAT cards) must also be input.

21 Covariance Matrix Card(s) (a-priori $(A^TA)^{-1}$) (optional input)

		1-2	Covariance Matrix Card Number (e.g. 01, 02, 03,...).
		3-4	Differential Correction Iteration Number (optional).
		5-9	UPMAT = Card type.
		10-23 *	Value of an element of the a-priori $(A^TA)^{-1}$ matrix.
		24-42 *	Value of an element of the a-priori $(A^TA)^{-1}$ matrix.
		48-61 *	Value of an element of the a-priori $(A^TA)^{-1}$ matrix.
		67-80 *	Value of an element of the a-priori $(A^TA)^{-1}$ matrix.

NOTE: An asterisk indicates a floating point field.

NOTE: As many covariance matrix cards are input (sequentially numbered) as are necessary to completely give the matrix. Restrictions: The maximum covariance matrix size is 8 x 8. A covariance matrix entered

Deck Position	Card Type	Column Number	Punch

by UPMAT cards may only contain Category One variables. A CAT1 card (punched to indicate the respective variables appearing on the UPMAT cards) must be input whenever UPMAT cards are input.

NOTE: As the covariance matrix is symmetric, only the lower triangular part of the matrix is input. They are input in the following order: the first element of the first row, the first two elements of the second row from left to right, the first three elements of the third row from left to right, etc.

Zonal Harmonic Card (If this card is omitted, ESPOD assumes a standard set: J_2, J_3, J_4).

Column Number	Punch
1-2	01 = Card Number.
5-9	ZONAL = Card type.
10	0 = Do not include J_2 in the earth gravitational potential model.
	1 = Include J_2 in the earth gravitational potential model.
11	0 = Do not include J_3.
	1 = Include J_3.
12	0 = Do not include J_4.
	1 = Include J_4.
13	0 = Do not include J_5.
	1 = Include J_5.

Deck Position	Card Type	Column Number	Punch
		14	0 = Do not include J_6.
			1 = Include J_6.
		15	0 = Do not include J_7.
			1 = Include J_7.
		16	0 = Do not include J_8.
			1 = Include J_8.
		17	0 = Do not include J_9.
			1 = Include J_9.
		18	0 = Do not include J_{10}.
			1 = Include J_{10}.
		19	0 = Do not include J_{11}.
			1 = Include J_{11}.
		20	0 = Do not include J_{12}.
			1 = Include J_{12}.

NOTE: Values of J_{10}, J_{11}, J_{12} must be input on 99 cards.

Sectorial Harmonics Card (If this card is omitted, no sectorial harmonics are included).

		1-2	01 = Card number.
		5-9	SECTR = Card type.
		10	0 = Do not include J_2^2 in the earth gravitational potential model.
			1 = Include J_2^2 in the earth gravitational potential model.

Deck Position	Card Type	Column Number	Punch
		11	0 = Do not include J_3^3.
			1 = Include J_3^3.
		12	0 = Do not include J_4^4.
			1 = Include J_4^4.
		13	0 = Do not include J_5^5.
			1 = Include J_5^5.
		14	0 = Do not include J_6^6.
			1 = Include J_6^6.
	Tesseral Harmonics Card (If this card is omitted, no tesseral harmonics are included).		
		1-2	01 = Card number.
		5-9	TESSR = Card type.
		10-11	Value of n_1 and m_1 respectively means include the term $J_{n_1}^{(m_1)}$ in the earth's gravitational potential model.
		13-14	Value of n_2 and m_2 respectively means include the term $J_{n_2}^{(m_2)}$.
		16-17	Value of n_3 and m_3 respectively means include the term $J_{n_3}^{(m_3)}$.
		19-20	Value of n_4 and m_4 respectively means include the term $J_{n_4}^{(m_4)}$.

Deck Position	Card Type	Column Number	Punch
		22-23	Value of n_5 and m_5 respectively means include the term $J_{n_5}^{(m_5)}$.
		29-30	Value n_6 and m_6 respectively means include the term $J_{n_6}^{(m_6)}$.
		32-33	Value of n_7 and m_7 respectively means include the term $J_{n_7}^{(m_7)}$.
		35-36	Value of n_8 and m_8 respectively means include the term $J_{n_8}^{(m_8)}$.
		38-39	Value of n_9 and m_9 respectively means include the term $J_{n_9}^{(m_9)}$.
		41-42	Value of n_{10} and m_{10} respectively means include the term $J_{n_{10}}^{(m_{10})}$.
		48-49	Value of n_{11} and m_{11} respectively means include the term $J_{n_{11}}^{(m_{11})}$.
		51-52	Value of n_{12} and m_{12} respectively means include the term $J_{n_{12}}^{(m_{12})}$.
		54-55	Value of n_{13} and m_{13} respectively means include the term $J_{n_{13}}^{(m_{13})}$.

Deck Position	Card Type	Column Number	Punch
		57-58	Value of n_{14} and m_{14} respectively means include the term $J_{n_{14}}^{(m_{14})}$.

NOTE: Any or all of the following fourteen terms may be chosen: $J_3^{(1)}$, $J_3^{(2)}$, $J_4^{(1)}$, $J_4^{(2)}$, $J_4^{(3)}$, $J_5^{(1)}$, $J_5^{(2)}$, $J_5^{(3)}$, $J_5^{(4)}$, $J_6^{(1)}$, $J_6^{(2)}$, $J_6^{(3)}$, $J_6^{(4)}$, $J_6^{(5)}$. Subscripts and superscripts not punched on the TESSR card will be excluded from the geopotential model. Values of $J_5^{(1)}$ through $J_6^{(5)}$ must be entered on 99 cards.

Deck Position	Card Type	Column Number	Punch
	New Constants Card (This card used if and only if one wishes to override any particular constant in ESPOD with a new value for a particular run.)		
		1-2	99 = Card type.
		5-9	Location number of the constant (right adjusted) (obtained from the master list).
		10-23 *	Value of the new constant whose location is given in col. 5-9.
		24-28	Location number of a constant (right adjusted).
		29-42 *	Value of the new constant whose location is given in col. 24-28.
		43-47	Location number of a constant (right adjusted).
		48-61 *	Value of the new constant whose location is given in col. 43-47.
		62-66	Location number of a constant (right adjusted).

NOTE: Asterisk means decimal point must appear somewhere in field.

Deck Position	Card Type	Column Number	Punch
		67-80 *	Value of the new constant whose location is given in col. 62-66.

NOTE: Unneeded fields may be left blank.

Standard Element Set (with blank, 1 or 2 in col. 68 of Card 7).

Updating Elements Parameter Card (This card used if and only if one wishes to update a seven-card element set to a different epoch).

		1-2	01 = Card number.
		5-9	DNREV = Card type.
		10-23 *	1.0 = Update the seven-card element set to a specified time given in days and fractions of days in cols. 29-42*.
			2.0 = Update the seven-card element set a specified number of revolutions past the epoch of the element set, the number being given in col. 29-42* (this number may be fractional).
			3.0 = Update the seven-card element set to a specified revolution number given in col. 29-42*.
			-1.0 = Update to the time of the last observation.

NOTE: An asterisk denotes a field which must contain a decimal point.

Deck Position	Card Type	Column Number	Punch
		29-42 *	Days and fractions to which to update, or Number of revolutions to update past epoch, or Revolution Number to which to update, or Blank (if update to time of last observation).

NOTE: Elements on cards are not updated unless a DNREV card is present. Elements from the E-file are updated to the time of the last observation unless a DNREV card is present.

Delete Residuals Card(s) (These cards used if and only if one wishes to delete particular residuals from consideration in all iterations of a run).

1-2	Delete Residual Card Number (e.g. 01, 02, 03...).	
5-9	DELET = Card type.	
10-16 *	Beginning Residual Number	Causes deletion for all included numbers.
17-23 *	Ending Residual Number	
29-35 *	Beginning Residual Number	Causes deletion for all included numbers.
36-42 *	Ending Residual Number	
48-54 *	Beginning Residual Number	Causes deletion for all included numbers.
55-61 *	Ending Residual Number	
67-73 *	Beginning Residual Number	Causes deletion for all included numbers.
74-80 *	Ending Residual Number	

NOTE: More than one of these cards may be used. Unneeded fields should be left blank.

NOTE: Asterisk indicates a floating point field.

Deck Position	Card Type	Column Number	Punch

Dynamic Atmosphere Parameter Card(s) (Omitted if a dynamic atmosphere is not used).

		1-2	Dynamic Atmosphere Parameter Card Number (e.g. 01, 02, etc.)
		5-9	APF10 = Card type.
		10-13 *	Day number in the year.
		14-18 *	Value of Ap for the day in col. 10-13.
		19-23 *	Value of F_{10} for the day in col. 10-13.
		29-32 *	Day number in the year.
		33-37 *	Value of Ap for the day in col. 29-32.
		38-42 *	Value of F_{10} for the day in col. 29-32.
		48-51 *	Day number in the year.
		52-56 *	Value of Ap for the day in col. 48-51.
		57-61 *	Value of F_{10} for the day in col. 48-51.
		67-70 *	Day number in the year.
		71-75 *	Value of Ap for the day in col. 67-70.
		76-80 *	Value of F_{10} for the day in col. 67-70.

<u>NOTE</u>: Asterisk denotes a floating point field.

<u>NOTE</u>: 30 is maximum number of sets of one value of Ap and one value of F_{10} which may be entered. Thus there can never be more than eight APF10 cards.

<u>NOTE</u>: If days are omitted between two day numbers, a linear interpolation is done.

Deck Position	Card Type	Column Number	Punch
	Ephemeris Specification Card(s)		
		1-2	Ephemeris Specification Card Number (01, 02, 03, 04).
		5-9	DELTT = Card type.
		10-23 *	Value (in minutes of step size between successive calculated positions).
		29-42 *	Time (in minutes) since epoch of the last point of the calculated positions at the step size given in col. 10-23.
		48-61 *	Value (in minutes) of another step size between successive calculated positions.
		67-80 *	Time (in minutes) since epoch of the last point of the calculated positions at the step size given in col. 48-61.

NOTE: A maximum of four Ephemeris Specification cards may be used.

NOTE: The step size may be negative, indicating an ephemeris calculated backwards in time.

Deck Position	Card Type	Column Number	Punch
30	Prediction Specification Card		
		1-2	01 = Card number.
		5-9	PRDCT = Card type.

NOTE: An asterisk indicates a floating-point field.

Deck Position	Card Type	Column Number	Punch
		10-23 *	Time (in days and fractions of days) of first prediction point.
		29-42 *	Time (in days and fractions of days) of second prediction point.
		48-61 *	Time (in days and fractions of days) of third prediction point.
		67-80 *	Time (in days and fractions of days) of fourth prediction point.

NOTE: Only one PRDCT card may be used in any run; i.e. the maximum number of specific prediction times is four.

NOTE: Unneeded time of prediction fields may be left blank.

Deck Position	Card Type	Column Number	Punch
	Time Step Specification Card (If this card is omitted, ESPOD uses a variable time step size in the numerical integration).		
		1-2	01 = Card number.
		5-9	TSTEP = Card type.
		10-23 *	Time step size (in minutes) to be used throughout the numerical integration.
	Maximum Time Specification Card (If this card is omitted, ESPOD will automatically disregard observations which are more than ten days from epoch).		

NOTE: An asterisk denotes a floating-point field.

Deck Position	Card Type	Column Number	Punch
		1-2	01 = Card number.
		5-8	TMAX = Card type.
		10-23 *	Maximum time in days and fractions from epoch for which observations are to be used. (Observations are disregarded if more than this number of days from epoch).
	Radiation Pressure Parameter Card (This card is only for radiation pressure perturbations).		
		1-2	01 = Card number.
		5-9	RADPR = Card type.
		10-23 *	Effective Area of satellite in square meters.
		29-42 *	Mass of satellite in kilograms.
	End Preliminary Data Card		
		5-9	ENDPR = Card type.
	Standard SPADATS Observation Cards (Not required if no DC is to be done).		

NOTE: If observation cards are input, col. 31 of the JDC card must have a one-punch. If there are less than 650 observations, they may be in any temporal order; if more than 650, they must be in descending time order. There is no maximum limit to the number of observations.

Deck Position	Card Type	Column Number	Punch
	End Observations Card (Required only if observation cards are input).		
		5-9	ENDOB = Card type.

NOTE: An asterisk denotes a floating-point field.

Deck Position	Card Type	Column Number	Punch
	Standard SPADATS Sensor Cards		
		(Standard SPADATS Sensor cards)	
		(Input if and only if one wishes to override or supplement the sensor file on the SEAI tape).	
		(If sensor cards are input, columns 31 and 34 of the JDC card must have a one-punch).	
	End Sensor Card (This card is input if and only if sensor cards are input).		
		5-9	ENDSN = Card type.
N	End Date Card (Last card of all ESPOD decks).		
		5-9	ENDAT = Card type.
N+1	End of Data Card		
N+2	End of Job Card		
N+3	End of Schedule Tape Card		
N+4	Blank Card		

4.3.1.3 Output

The program provides output on both hard copy and punched cards.

4.3.1.3.1 Program Printout

Part 1: Lists the input cards, with the columns of the printout corresponding exactly with the columns of the cards.

Part 2: General

a. Type of observations.

b. Satellite number and name.

c. Type of program run (e.g. COLD START or NON-COLD START).

d. Right ascension of Greenwich at 2400 on day of epoch (ALPHA G ZERO).

e. Epoch time of the program run.

f. Initial conditions.

X - Position vector (km).	
Y - Position vector (km).	Geocentric
Z - Position vector (km).	Inertial
XDOT - Velocity vector (km/sec).	Cartesian
YDOT - Velocity vector (km/sec).	Coordinates
ZDOT - Velocity vector (km/sec).	
ALPHA - Right ascension (deg).	
DELTA - Declination (deg).	Geocentric
BETA - Flight path angle (deg).	Inertial
A - Azimuth (deg).	Spherical
R - Range (km).	Coordinates
V - Velocity (km/sec).	

CDA/2M (optional) - Atmospheric drag parameter ($meters^2$/kilogram).

Part 3: Program Constants (optional).

Part 4: Sensor Information (printed if Part 3 is requested).

1. SENSOR NO. - Sensor number.
2. SIGMA TYPE - Standard deviation category applied to the sensor.
3. RANGE/RA(FR) - Standard deviation in range/standard deviation in right ascension for a field-reduced observation from a Baker-Nunn camera.
4. AZ/DEC(FR) - Standard deviation in azimuth/standard deviation in declination for a field-reduced observation from a Baker-Nunn camera.
5. EL/RA(PR) - Standard deviation in elevation/standard deviation in right ascension for a precision-reduced observation from a Baker-Nunn camera.
6. RDT/DEC(PR) - Standard deviation in range rate/standard deviation in declination for a precision-reduced observation from a Baker-Nunn camera.
7. GSUBS - Gross outlier editing criterion for the observations in terms of N sigma.
8. REFR. FLAG - Refraction correction indicator (1 = applied, 0 = not applied).
9. NSUBS = Refraction index for the time of interest.

Part 5: Observation Type

1. ID - Sensor number.
2. T-TO - Time of observation (min. from epoch).
3. YR, MN, DAY, HR, MIN, SEC - Time observation (Greenwich time).
4. R - Range (km).
5. A - Azimuth (deg).
6. EL - Elevation (deg).
7. R DOT - Range rate (km/sec).
8. HA - Hour angle (deg), in lieu of azimuth.
9. D - Declination (deg), in lieu of elevation.

Part 6: Sensor Locations

1. ST. NO. - Sensor number.
2. LAT. - Sensor latitude north (deg).
3. LONG. - Sensor longitude west (deg).
4. ALT. - Sensor altitude (meters).

Part 7: Residuals Print

1. ID - Sensor number.
2. DATE - Time of the observation from which the residuals were obtained.
3. N - Residual number.
4. RANGE KM - Range residual (km).
5. AZ,HA DEG. - Azimuth/hour angle residual (deg).
6. EL,DC DEG. - Elevation/declination residual (deg).

7. RDOT KM/SEC - Range rate residual (km/sec).

8. U KM (see notes) - Up component of the position residual (km) collinear with and positive in the same direction as the radius vector.

9. V KM (see notes) - Down component of the position residual (km), orthogonal to the radius vector, in the orbit plane, positive in the direction of motion.

10. W KM (see notes) - Cross component of the position residual (km), normal to the orbit plane and positive in the direction of the angular momentum vector to complete a right-handed coordinate system.

11. VM KM - Magnitude of the position residual or displacement vector (km).

12. DEL T MIN - Time separation of computed and measured positions (min), assuming Keplerian mean motion.

13. U DEG - Argument of latitude (deg), angle from the ascending node to the radius vector.

14. BETA DEG. - Residual angle between the measured position vector and the computed orbit plane.

<u>NOTE</u>: One of three symbols may appear following any numerical value, indicating deletion of the residual from further calculations:

* = DELETE input deletion.

G = Gross outlier deletion.

K = KRMS test deletion.

NOTE: U KM, V KM, and W KM may be optionally replaced by normal, tangential and cross-directional components of a vector describing the displacement of the observed with respect to the computed position:

S KM - Vector component (km), orthogonal to the velocity vector and in the orbit plane, forming a right-handed coordinate system with T and W.

T KM - Vector component (km), collinear with and in the same direction as the velocity vector.

W KM - Vector component (km), normal to the orbit plane and in the same direction as the angular momentum vector.

NOTE: U KM, V KM and W KM may be optionally replaced by components of a vector describing the displacement of the sensor which would be required to reduce the residual to zero.

ST. LAT DEG - Geocentric north latitude displacement (deg).

ST. LONE DEG - East longitude displacement (deg).

ST. HT KM - Height displacement (km above mean equatorial sea level).

Part 8: Estimates of Mean and Standard Deviations by Sensor and Type.

1. ST. ID. - Sensor number.
2. R - Range values (km).
3. A,HA - Azimuth or hour angle values (deg).
4. E,D - Elevation or declination values (deg).
5. RDOT - Range rate values (km/sec).
6. MEAN - Arithmetic mean.
7. ESTD - Estimated standard deviation (one sigma) of the mean.
8. NA/NR - Number of observations accepted/number of observations rejected.

Part 9: Curve Fit Iteration Summary

1. Category 1 variables:

   ALPHA - Right ascension (deg).

   DELTA - Declination (deg).

   BETA - Flight path angle (deg).

   AZ - Azimuth to inertial velocity vector (deg).

   R - Radius vector from geocenter (km).

   V - Velocity vector magnitude (km/sec).

   CDA/2M - Drag parameter (meters^2/kilogram).

   K - Drag variation (secular option: meters^2/kilogram/day; periodic option: meters^2/kilogram.

2. DELTA - the corrections applied to each variable.

3. OLD - Numerical values from the previous iteration.

4. NEW - OLD + DELTA.

5. SIGMA - The uncertainty in each variable, computed from the covariance matrix.

6. BOUNDS - The constraints applied to the changes which the program is allowed to make to the variables.

7. Category 2 variables:

   R - Range (km).

   A,HA - Azimuth or hour angle (deg).

   E,D - Elevation or declination (deg).

   RDOT - Range rate (km/sec).

   LAT - Sensor north latitude (deg).

LONG - Sensor east longitude (deg).

ALT - Sensor altitude (meters).

T - Time (sec).

8. DELTA, OLD, NEW, SIGMA, BOUNDS - same as for Category 1 variables.
9. Convergence statement.
10. Bounds statement.
11. CURRENT RMS - Current root-mean-square of the residuals.
12. PREDICTED RMS - The RMS predicted for the next iteration.
13. BEST RMS - The best RMS so far in the curve fit run.
14. DELTA V - The velocity correction based on the delta t fit.
15. RMS DEL T - Current root-mean-square of the time residuals.
16. PREDICTED RMS DEL T - The RMS predicted for the next iteration.
17. Correlation matrix, with rows and columns numbered to correspond to the Category 1 variables.
18. Covariance matrix, with rows and columns numbered to correspond to the Category 1 variables.
19. Run termination statement.

Part 10: Trajectory (or Ephemeris)

1. Date and Greenwich mean time for the data.
2. Time from epoch (min).
3. Time from January 0 of the year of epoch (days).

4. X, Y, Z, XDOT, YDOT, ZDOT - Components of the position (km) and velocity (km/sec) vector in geocentric inertial Cartesian coordinates. It is a right-handed orthogonal system where the X axis is in the direction of the vernal equinox and the Z axis is in the direction of true north. Coordinates are true as of $0^{h}.0$ day of epoch.

5. Polar spherical position and velocity coordinates (ADBARV):

   ALFA - Right ascension (deg).

   DLTA - Declination (deg).

   BETA - Flight path angle (deg), positive downward from the local vertical.

   AZ - Azimuth of the velocity vector (deg).

   R - Range (km).

   V - Magnitude of the velocity vector (km/sec).

6. ALT - Height (km).

7. LAT - Geodetic north latitude (deg).

8. LONE - East longitude (deg).

9. Classical osculating elements:

   SMA - Semimajor axis (km).

   ECC - Eccentricity.

   INC - Inclination (deg).

   NODE - Right ascension of the ascending node (deg).

   OMG - Argument of perigee (deg).

   M - Mean anomaly (deg).

10. UX, UY, UZ - Direction cosines of the position in Cartesian coordinates, with axes directed as in the XYZ system.

11. RPVX, RPVY, RPVZ - Components in Cartesian coordinates of a vector in the orbit plane which is orthogonal to the position ($\underline{r}$) and angular momentum ($\underline{h}$) vectors.

12. ALAT - Argument of latitude (deg), equals the sum of the argument of perigee and the true anomaly.

13. TAU - Time until the next ascending nodal crossing (min. from epoch).

14. PRD - Osculating orbital period (min).

15. Indeterminacy free elements:

    1/A - Inverse of the semimajor axis (E.R.).

    D - Scalar product of position and velocity vectors ($E.R.^{\frac{1}{2}}$), equals $(R \cdot \dot{R}) \div \sqrt{\mu}$.

16. APOG - Apogee distance (km), above a mean equator.

17. PRG - Perigee distance (km), above a mean equator.

18. ELLIPSE or HYPERBOLA - Orbit's conic form.

19. XVM, YVM, ZVM, XDVM, YDVM, ZDVM - Selenocentric position (km) and velocity (km/sec) coordinates, true as of $0\overset{h}{\cdot}0$ day of epoch.

20. XVS, YVS, ZVS, SDVS, YDVS, ZDVS - Heliocentric position (km) and velocity (km/sec) coordinates, true as of $0\overset{h}{\cdot}0$ day of epoch.

21. DVFM - Distance from the vehicle to the selenocenter (moon) (km).

22. DVFS - Distance from the vehicle to the heliocenter (sun) (km).

In addition to the above items, the following are optional:

23. ORBIT PLANE SIGMA AND RHO MATRIX - A matrix of standard deviations (diagonal terms) and correlation coefficients (off-diagonal terms) related to the UVW Orbit Plane coordinates:

U - Position vector (up) component (km) in the direction of and collinear with the radius vector.

V - Position vector (down) component (km) in the direction of motion and orthogonal to the radius vector in the orbit plane.

W - Position vector (cross) component (km) normal to the orbit plane in the direction of the angular momentum vector to complete a right-handed coordinate system.

UDOT - Velocity vector of U.

VDOT - Velocity vector of V.

WDOT - Velocity vector of W.

CDA/2M - Drag parameter (meters^2/kilogram).

<u>or</u>

K - Drag variation parameter (for secular option: meters^2/kilogram/day; for periodic option: meters^2/kilogram).

24. EIGENVECTORS OF U, V, W COVARIANCE MATRIX - Direction cosine components with respect to the U, V, W axes for the orthogonal axes of the error ellipsoid defined by the covariance matrix.

25. SQUARE ROOTS OF THE EIGENVALUES - Represent the lengths of the orthogonal semi-principal axes of the error ellipsoid.

26. TO ALIGN U, V, W WITH THE PRINCIPAL AXES - A series of ordered rotations which will reposition an observer, facing initially in the positive V direction, to a new orientation facing along the error ellipsoid's nearest principal axis:
YAW RIGHT - (deg).
PITCH DOWN - (deg).
ROLL CLOCKWISE - (deg).

27. POLAR SIGMA AND RHO MATRIX - A matrix of standard deviations (diagonal terms) and correlation coefficients (off-diagonal terms) related to the Polar Spherical coordinates: ALPHA, DELTA, BETA, AZ, R AND V.

28. CARTESIAN SIGMA AND RHO MATRIX - A matrix of standard deviations (diagonal terms) and correlation coefficients (off-diagonal terms) related to the geocentric inertial Cartesian coordinates: X, Y, Z XDOT, YDOT, ZDOT.

4.3.1.3.2 Punched Csrds

The program provides punched card output in three formats.

Part 1: Seven-card Element Set

The program provides OLD or NEW osculating elements, as requested in col. 46 of the JDC card.

Part 2: Solution Parameters

The program provides a record of data from a run in a format identical with

selected input card formats, for use in subsequent input decks. The data are grouped by iteration, and each output card contains the iteration number in cols. 3-4. The output cards can be read by referring to the corresponding input cards: ICOND, DRAG, BISES, BNDS, ICTYP, ITIME, SMAT, UPMAT.

Part 3: DAC Parameters

The program automatically provides the second and third card of a 3-card DAC set when DAC cards are input to supply the desired update times. The first card must be provided by the Analyst before using this output as input to another program (see Message Header card for the GIPAR program). The output cards can be read by referring to the corresponding input cards.

SAMPLE PRINTOUT, ESPOD

```
PART 1  INPUT CARDS
   JDCUE49196R ETA 3           0101 11     1     2
   01  NEW   RADAR OBS
   01  ICPNE88.93608           19.89644          89.06378          159.1810
   02  ICCNE7379.367           7.260806
   01  ITTME64.0               2.0               19.0              7.0
   02  ITTME56.0               30.0
   01  ICTYP1.0
   01  CAT1 111111
   01  CAT2 09341
       ENCPR
```

```
PART 2,  GENERAL

                 RADAR OBS

                        VEHICLE NO.     0047      1960 ETA 3

                                    COLD START

                                  ALPHA G ZERO
                                    144.84053

                                   EPOCH TIME
                       YEAR   MONTH   DAY   HOUR   MINUTES   SECONDS
                        64      9      15     7       56      35.99

                                 INITIAL CONDITIONS
       X                Y                Z               XDOT             YDOT             ZDOT
 .425404686+3     .692383894+4     .251159670+4    -.269544711+1     .254637173+1    -.615102005+1

     ALPHA            DELTA            BETA              A                E                V
 .868348799+2     .196984399+2     .890637600+2     .155181799+3     .737936699+4     .726866688+1
```

SAMPLE PRINTOUT, ESPOD

PART 3, PROGRAM CONSTANTS

PROGRAM CONSTANTS

141	142	143	144	145	146
.437726909-2	.335230000-2	.320875980+2	.553039340-2	.099999999+1	.182998960-1
147	148	149	150	151	152
.332951299+6	.81476904999	.10782099998	.949520000+2	.317886649+3	.00000000000
153	154	155	156	157	158
.099999999+1	.099999999+1	.00000000000	.00000000000	.00000000000	.00000000000
159	160	161	162	163	164
.108230000+2	-.229999999-5	-.179999999-5	-.640000000-7	.390000000-6	-.470000000-6
165	166	167	168	169	170
.200000000-7	.116999999-6	.00000000000	.00000000000	.00000000000	.00000000000
171	172	173	174	175	176
.00000000000	.395000000-5	.264000000-5	.00000000000	.00000000000	.00000000000
177	178	179	180	181	182
.232000000-5	.410000000-6	.167000000-5	.00000000000	.00000000000	.219999999+2
183	184	185	186	187	188
.309999999+2	.190999999-5	.459999999-6	.00000000000	.00000000000	.163499999+3
189	190	191	192	193	194
.539999999+2	-.130000000+2	.560000000-6	.00000000000	.00000000000	.00000000000
195	196	197	198	199	200
.00000000000	.00000000000	.00000000000	.00000000000	.00000000000	.00000000000
201	202	203	204	205	206
.00000000000	.00000000000	.00000000000	.00000000000	.00000000000	-.375000000+2
207	208	209	210	211	212
.513000000+2	.503000000+2	.00000000000	.00000000000	.00000000000	.00000000000
213	214	215	216	217	218
.00000000000	.00000000000	.209257381+8	.384799999-3	.637816499+4	.637816499+4
219	220	221	222	223	224
.637816499+7	.234548649+5	.572957795+2	.687611519+4	.344393400+4	.100302749+3

PART 4, SENSOR INFORMATION (NO EXAMPLE GIVEN)

SAMPLE PRINTOUT, ESPOD

PART 5. OBSERVATION TYPE

OBSERVATION TYPE

TD	T-T0	YR	MO	DAY	HR	MIN	SEC	R	A	EL	R DOT	W4	D
0339	-305.241	64	[illegible]	15	2	51	15.519	1185.34	206.6690	57.3700	1.7556959	.0000	.0000
0339	-305.441	64	[illegible]	15	2	51	9.525	1147.73	213.5300	58.6799	1.8207759	.0000	.0000
0339	-305.541	64	[illegible]	15	2	51	3.530	1139.56	217.5199	60.6000	1.6287599	.0000	.0000
0339	-305.641	64	[illegible]	15	2	50	57.536	1131.01	220.1399	61.6700	1.4797479	.0000	.0000
0339	-305.741	64	[illegible]	15	2	50	51.521	1119.02	224.2499	62.8800	1.2649159	.0000	.0000
0339	-305.841	64	[illegible]	15	2	50	45.526	1110.63	229.7399	63.4999	1.0223039	.0000	.0000
0339	-305.941	64	[illegible]	15	2	50	39.511	1102.91	235.1699	63.7600	.7796920	.0000	.0000
0339	-306.141	64	[illegible]	15	2	50	27.502	1099.32	244.0699	64.6399	.3185439	.0000	.0000
0339	-306.241	64	[illegible]	15	2	50	21.508	1106.36	249.7399	64.2200	.0259279	.0000	.0000
0339	-306.341	64	[illegible]	15	2	50	15.513	1008.96	255.6899	44.4000	-.1759390	.0000	.0000
0339	-306.441	64	[illegible]	15	2	50	9.519	1102.40	259.0499	64.4000	-.4241080	.0000	.0000
0339	-306.541	64	[illegible]	15	2	50	3.504	1111.30	264.3899	63.7600	-.6778320	.0000	.0000
0339	-306.641	64	[illegible]	15	2	40	57.509	1101.55	269.3999	63.1499	-.8574759	.0000	.0000
0339	-306.741	64	[illegible]	15	2	49	51.515	1107.49	274.6299	62.2700	-1.0815679	.0000	.0000
0339	-306.841	64	[illegible]	15	2	40	45.520	1132.14	278.0999	61.4300	-1.2982519	.0000	.0000
0339	-306.941	64	[illegible]	15	[illegible]	49	39.505	1117.52	279.9900	60.8799	-1.7149519	.0000	.0000
0339	-307.041	64	[illegible]	15	2	49	33.511	1145.62	285.1099	59.1699	-1.7875479	.0000	.0000
0339	-307.140	64	[illegible]	15	2	49	21.543	1166.83	289.6199	57.0999	-2.2094359	.0000	.0000
0339	-307.341	64	[illegible]	15	2	49	15.528	1197.70	293.2600	55.0999	-2.4603440	.0000	.0000
0339	-307.441	64	[illegible]	15	2	49	9.533	1100.69	297.6599	54.2000	-2.6057639	.0000	.0000
0339	-307.541	64	[illegible]	15	2	49	3.539	1195.31	299.0599	53.1699	-2.7335520	.0000	.0000
0339	-307.640	64	[illegible]	15	2	48	57.545	1238.57	302.1599	51.4100	-2.9113440	.0000	.0000
0339	-307.741	64	[illegible]	15	2	48	51.529	1238.05	303.3500	49.8699	-2.8780079	.0000	.0000
0339	-307.841	64	[illegible]	15	2	48	45.535	1257.22	304.7099	48.7499	-3.1009959	.0000	.0000
0339	-308.041	64	[illegible]	15	2	48	33.526	1295.13	308.3399	45.9899	-3.5262080	.0000	.0000
0339	-308.141	64	[illegible]	15	2	48	27.531	1304.37	305.6999	44.9100	-3.6706640	.0000	.0000
0744	-308.610	64	[illegible]	15	2	47	59.303	.00	280.7973	9.7000	.0000000	.0000	.0000
0743	-308.610	64	[illegible]	15	2	47	59.393	.00	275.6697	34.4990	.0000000	.0000	.0000
0742	-308.610	64	[illegible]	15	2	47	59.393	.00	86.6597	88.2999	.0000000	.0000	.0000
0741	-308.610	64	[illegible]	15	2	47	59.393	.00	81.4416	39.1600	.0000000	.0000	.0000
0336	-403.957	64	[illegible]	15	1	12	38.557	3141.07	175.2499	5.7600	5.8352816	.0000	.0000
0336	-404.123	64	[illegible]	15	1	12	28.587	3082.06	175.6899	6.4100	5.8165763	.0000	.0000
0336	-404.290	64	[illegible]	15	1	12	18.597	3024.02	176.0800	7.0299	5.8089832	.0000	.0000
0336	-404.456	64	[illegible]	15	1	12	8.627	2965.09	176.4799	7.6000	5.8388003	.0000	.0000
0336	-404.622	64	[illegible]	15	1	11	58.636	2908.19	176.6999	8.3000	5.7602392	.0000	.0000
0336	-404.789	64	[illegible]	15	1	11	48.645	2851.27	177.3399	8.9800	5.7460151	.0000	.0000
0336	-404.955	64	[illegible]	15	1	11	38.675	2792.55	177.6199	9.6599	5.7182352	.0000	.0000
0336	-405.121	64	[illegible]	15	1	11	28.684	2736.80	178.2599	10.4099	5.6056407	.0000	.0000
0336	-405.288	64	[illegible]	15	1	11	18.714	2678.60	178.6099	11.5099	5.6652679	.0000	.0000
0336	-405.454	64	[illegible]	15	1	11	8.724	2623.11	179.3599	11.8399	5.6326727	.0000	.0000
0336	-405.621	64	[illegible]	15	1	10	58.733	2567.33	179.6899	12.6300	5.6019295	.0000	.0000
0336	-405.787	64	[illegible]	15	1	10	48.743	2511.45	180.4999	13.3999	5.5660007	.0000	.0000
0336	-405.953	64	[illegible]	15	1	10	38.772	2455.65	181.1599	14.1699	5.5107708	.0000	.0000
0336	-406.458	64	[illegible]	15	1	10	8.821	2292.84	183.2280	16.6900	5.3841343	.0000	.0000
0336	-406.785	64	[illegible]	15	1	9	48.840	2186.61	184.6299	18.5200	5.2691251	.0000	.0000
0336	-406.952	64	[illegible]	15	1	9	38.869	2134.05	185.7200	19.4590	5.2037495	.0000	.0000
0336	-407.284	64	[illegible]	15	1	9	18.908	2031.30	187.6399	21.4399	5.0563304	.0000	.0000
0336	-407.451	64	[illegible]	15	1	9	8.938	94580.09	188.7199	22.4099	4.9215087	.0000	.0000
0336	-407.619	64	[illegible]	15	1	8	58.948	1931.00	189.6399	23.4799	4.8296495	.0000	.0000
0336	-407.784	64	[illegible]	15	1	8	48.857	1883.81	191.6780	24.5399	4.7886047	.0000	.0000

PART 6. SENSOR LOCATIONS (NO EXAMPLE GIVEN)
PART 7. RESIDUALS PRINT

RESIDUALS PRINT

TD	DATE Y	MM	DD	HH	MM	SS.SS	N	RANGE KM	AZ.HA DEG.	EL.DC DEG.	RDOT KM/SEC	U KM	V KM	W KM	VM KM	DEL T MIN	D DEG.	BETA DEG.
0339	4	2	15	2	51	15.51	1	40.294	-2.905	-.571	-.406	30.34	42.67	-3.87	52.90	.097	154.42	-.029
0339	4	2	15	2	51	9.55	5	15.037	.527	-.411	-.128	9.86	2.69	-14.77	17.96	.006	154.08	-.114
0339	4	2	15	2	51	3.55	9	17.974	1.000	.429	-.117	19.84	-8.61	-4.66	22.13	-.019	153.74	-.036
0339	4	2	15	2	50	57.55	13	19.247	-.196	.507	-.049	21.63	1.15	1.79	21.73	.002	153.40	.013
0339	4	2	15	2	50	51.52	17	15.787	-.220	.630	-.041	20.88	-1.26	8.63	22.63	-.002	153.06	.046
0339	4	2	15	2	50	45.52	21	14.545	.857	.691	-.055	18.56	-9.05	4.26	21.08	-.020	152.73	.033
0339	4	2	15	2	50	39.55	25	12.612	1.592	.336	-.065	14.07	-3.55	-1.54	19.60	-.031	152.39	-.012
0339	4	2	15	2	50	27.55	29	16.338	.508	.487	-.052	18.66	-4.30	2.39	19.24	-.009	151.71	.018
0339	4	2	15	2	50	21.55	33	24.888	1.024	-.024	-.106	22.86	-9.17	-9.21	26.30	-.020	151.37	-.071
0339	4	2	15	2	50	15.55	37	17.550	1.814	.251	-.067	18.01	-5.19	.29	23.56	-.034	151.03	.002
0339	4	2	15	2	50	9.55	41	19.623	.989	.533	-.076	21.98	-7.56	3.96	23.58	-.017	150.69	.030
0339	4	2	15	2	50	3.55	45	25.721	.479	.355	-.090	26.38	-5.09	-2.08	26.92	-.011	150.35	-.016
0339	4	2	15	2	49	57.55	49	11.734	.771	.391	-.034	13.71	-5.28	4.76	15.45	-.012	150.01	.007
0339	4	2	15	2	49	51.55	53	12.050	1.543	.266	-.025	13.04	-2.33	6.45	15.07	-.028	149.67	.050
0339	4	2	15	2	49	45.55	57	29.681	.844	.333	-.013	29.69	-10.20	-1.2	31.39	-.023	149.33	-.069
0339	4	2	15	2	49	39.56	61	6.651	-1.145	.605	-.204	12.71	15.46	2.99	20.25	.035	148.99	.023
0339	4	2	15	2	49	33.54	65	25.039	.408	.227	-.028	24.41	-7.77	-2.85	25.77	-.017	148.65	-.022
0339	4	2	15	2	49	21.54	69	25.010	-1.340	.566	-.061	25.60	9.88	-11.00	29.64	.022	147.97	-.085
0339	4	2	15	2	49	15.55	73	40.363	-.449	-.229	-.099	32.76	-14.41	-20.04	40.97	-.032	147.63	-.155
0339	4	2	15	2	49	9.55	77	18.684	1.648	.282	-.064	18.97	-5.69	12.65	27.04	-.036	147.29	.069
0339	4	2	15	2	49	3.55	81	7.523	.562	.592	-.007	12.84	1.01	9.61	16.07	.002	146.95	.074
0339	4	2	15	2	48	57.54	85	33.904	1.572	.183	-.007	30.53	-24.32	8.94	40.05	-.055	146.61	.069
0339	4	2	15	2	48	51.59	89	15.398	.842	.001	.196	12.74	-13.54	5.22	19.31	-.030	146.26	.040
0339	4	2	15	2	48	45.55	93	15.646	.448	.229	.046	15.69	-7.03	3.05	17.65	-.017	145.92	.023
0339	4	2	15	2	48	33.55	97	12.625	.980	.085	.014	11.32	-12.66	10.72	20.09	-.028	145.24	.043
0339	4	2	15	2	48	27.55	101	.415	1.173	.359	.010	5.31	-2.85	19.77	20.66	-.006	144.91	.154
0744	4	2	15	2	47	59.30	105	.000	.043	-.219	.000	-8.91	-4.10	-4.01	10.60	-.009	143.30	-.031
0743	4	2	15	2	47	59.30	107	.000	.072	-.271	.000	-6.97	-4.20	-3.96	9.02	-.009	143.30	-.030
0744	4	2	15	2	47	59.30	109	.000	-7.014	-.654	.000	-.24	2.81	11.04	11.40	.006	143.30	[illegible]
0741	4	2	15	2	47	59.30	111	.000	-.089	.032	.000	.53	-1.60	.20	1.68	-.004	143.30	[illegible]
0336	4	2	15	1	12	38.55	113	-5.872	-.060	.013	-.011	-2.39	-3.92	4.99	6.76	-.009	163.85	.038
0336	4	2	15	1	12	28.58	117	-6.665	.004	.051	-.014	-1.08	-6.76	2.31	7.23	-.015	163.29	.017
0336	4	2	15	1	12	18.59	121	-6.529	.002	.036	-.005	-1.74	-6.18	2.23	6.80	-.014	162.73	.017
0336	4	2	15	1	12	8.62	125	-7.577	-.004	.049	.042	-1.79	-7.15	3.06	7.99	-.016	162.17	.023
0336	4	2	15	1	11	58.61	129	-6.659	-.011	-.003	-.007	-3.61	[illegible]	2.61	6.68	-.011	161.60	[illegible]
0336	4	2	15	1	11	48.64	133	-5.992	-.017	.000	-.007	-3.12	-4.60	2.72	6.65	-.010	161.04	.021
0336	4	2	15	1	11	38.60	137	-7.454	-.002	.010	-.011	-3.56	-6.02	2.68	7.47	-.013	160.48	.020
0336	4	2	15	1	11	28.60	141	-6.088	-.051	.033	-.007	-1.88	-4.55	4.60	6.74	-.010	159.92	.035
0336	4	2	15	1	11	18.70	145	-7.573	-.013	.410K	-.009	12.17	-5.03	7.28	20.67	-.034	159.36	.055
0336	4	2	15	1	11	8.75	149	-6.509	-.031	-.000	-.011	-3.50	-4.97	2.30	6.50	-.011	158.79	.017
0336	4	2	15	1	10	58.75	153	-6.070	-.036	.030	-.008	-2.15	-4.62	3.90	6.42	-.010	158.23	.030
0336	4	2	15	1	10	48.76	157	-6.197	-.020	.023	-.007	-2.50	-4.83	3.25	6.34	-.011	157.67	.025
0336	4	2	15	1	10	38.77	161	-6.513	.012	-.004	-.013	-3.74	-5.02	1.85	6.53	-.011	157.10	.014
0336	4	2	15	1	10	8.85	165	-5.621	-.023	-.007	-.007	-3.40	-3.53	2.89	5.69	-.008	155.41	.022
0336	4	2	15	1	9	48.86	169	-5.347	-.022	.024	-.007	-2.29	-3.87	3.14	5.49	-.008	154.29	.024
0336	4	2	15	1	9	38.86	173	-5.516	-.003	.027	-.007	-2.37	-4.32	2.67	5.61	-.009	153.72	.020
0336	4	2	15	1	9	18.90	177	-5.687	-.024	.034	-.006	-2.39	-4.03	3.53	5.87	-.009	152.59	.027
0336	4	2	15	1	8	5.93	181	999.999G	-.006	.008	-.008	999.99	999.99	-999.99	999.99	13.187	152.03	-9.999
0336	4	2	15	1	8	58.94	185	-6.618	-.022	.032	-.009	-3.16	-4.46	3.94	6.74	-.010	151.46	.030
0336	4	2	15	1	8	48.95	189	-5.452	-.008	.018	-.007	-2.88	-3.63	2.94	5.49	-.008	150.90	.022
0336	4	2	15	1	8	38.94	193	-5.368	-.008	-.009	-.012	-3.36	-3.17	2.71	5.36	-.007	150.33	.021
0336	4	2	15	1	8	28.99	197	-6.212	-.006	.011	-.009	-3.69	-3.82	3.26	6.22	-.008	149.77	.025

SAMPLE PRINTOUT, ESPOD

PART 5. ESTIMATES OF MEANS AND STANDARD DEVIATIONS

ESTIMATES OF MEANS AND STANDARD DEVIATIONS BY SENSOR AND TYPE

ST. ID.	W	A,HA	E,D	R-OT	
0328	-.12121485+2	.3365911819	.6370825745	-.45304850-1	MEAN
	.10789303+2	.1079219753	.5656537314	.13890356-1	ESTD
	6 / 0	6 / 0	6 / 0	5 / 1	NA/NR
[illegible]	-.15063380+1	-.41845552-1	.53335567-1	-.85317580-2	MEAN
	.71057161+2	.7021206241	.6566368578	.17222211-1	ESTD
	25 / 0	25 / 0	25 / 0	25 / 0	NA/NR
0334	-.56347831+1	-.25044621-1	-.42605573-1	-.35772400-1	MEAN
	.90517879+1	.4899272681	.1805823292	.20763314-1	ESTD
	257 / 2	259 / 0	259 / 0	259 / 0	NA/NR
0339	.59735059+1	.16739610+1	.1543074336	-.1106804467	MEAN
	.13171419+2	.16186630+1	.7900708695	.1486672864	ESTD
	79 / 0	78 / 1	79 / 0	75 / 0	NA/NR
0741	.0000000000	-.22231236+1	-.5248137582	.0000000000	MEAN
	.0000000000	.18583345+1	.6288476240	.0000000000	ESTD
	0 / 0	2 / 0	2 / 0	0 / 0	NA/NR
0742	.0000000000	-.10523061+2	-.8182243091	.0000000000	MEAN
	.0000000000	.98280433+1	.3813073509	.0000000000	ESTD
	0 / 0	2 / 0	2 / 0	0 / 0	NA/NR
0743	.0000000000	-.22731984+1	-.2278247472	.0000000000	MEAN
	.0000000000	.31138312+1	.4605081324	.0000000000	ESTD
	0 / 0	3 / 0	3 / 0	0 / 0	NA/NR
0744	.0000000000	-.14485256+1	-.84461308-1	.0000000000	MEAN
	.0000000000	.14079202+1	.40871545+1	.0000000000	ESTD
	0 / 0	3 / 0	3 / 0	0 / 0	NA/NR

SAMPLE PRINTOUT, ESPOD

PART 6. SENSOR LOCATIONS (NO EXAMPLE GIVEN)

PART 7. RESIDUALS PRINT

SAMPLE PRINTOUT, ESPOD

PART 2. CURVE FIT ITERATION SUMMARY

ITERATION NUMBER 1

CATEGORY 1 VARIABLES		DELTA	OLD	NEW	SIGMA	BOUNDS
1	ALPHA	.00000000000	.862368799+2	.862368799+2	.209113212+2	.099999999+1
2	DELTA	.00000000000	.198984399+2	.198984399+2	.295342173+2	.099999999+1
3	BETA	.00000000000	.890637599+2	.890637599+2	.114709283+2	.20000000001
4	AT	.00000000000	.155101799+3	.155101799+3	.167963661+2	.50000000000
5	R	.00000000000	.737936699+4	.737936690+4	.14244467776	.099999999+1
6	V	-.111691562-3	.796088600+1	.726077430+1	.145579933+3	.99999999997

CATEGORY 2 VARIABLES		DELTA	OLD	NEW	SIGMA	BOUNDS
7 0336	RBIAS	.00000000000	.00000000000	.00000000000	.31161745323	.099999999+2

SOLUTION IS CONVERGING

SOLUTION IS NOT AFFECTED BY BOUNDS

CURRENT RMS	4.898711
PREDICTED RMS	1.193935
BEST RMS	4.898711

DEL T FIT SUMMARY

DELTA V	-.000111
RMS DEL T	.076329
PREDICTED RMS DEL T	.067678

CORRELATION MATRIX

	1	2	3	4	5	6	7
1	.0999999+1						
2	-.376574059	.0999999+1					
3	.464633898	-.700383487	.0999999+1				
4	.495800843	-.111663185	.180477658	.0999999+1			
5	.1600854-1	.1341058-1	.127267028	.1618259-1	.0999999+1		
6	.3201791-1	.1012797-1	-.1517027[illegible]	-.2317034-1	-.999639350	.0999999-1	
7	-.4798825-1	.3314366-1	-.9028303-1	-.6072025-1	-.5816146-1	.5992749-1	.0999999-1

ATA INVERSE

	1	2	3	4	5	6	7
1	.4372035-5						
2	-.8100289-5	.7401331-5					
3	.1114927-5	-.2212112-5	.1315821-5				
4	.1739342-5	-.5164140-6	.3477261-6	.2821179-5			
5	.3036555-5	.5950767-5	.2079508-4	.3871770-5	.2029048-1		
6	-.1002104-7	.4050726-8	-.2533339-7	-.5665645-8	-.2072960-4	.2419351-7	
7	-.3127875-4	.2045489-4	-.3227215-4	-.3178123-4	-.2581085-2	.2718675-5	.9710543-1

SAMP PRINTOUT, ESPOD

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PART 1Q  TRAJECTORY

 30 MAY        1964     2 HR   3 MIN  28.499 SEC  MINUTES FROM EPOCH       .00000   DAY OF YEAR 151.085746

   X  -.6852337296+4 XDOT  -.1983322470-1 ALFA   .1808523905+3   AZ   .1456460577+3  ALT   .9450927482+3
   Y  -.1019498912+3 YDOT  -.4147556454+1 DLTA   .2058718213+2    R   .7320602330+4  LAT   .2071416639+2
   Z   .2574159723+4 ZDOT  -.5666850709+1 BETA   .9061581086+2    V   .7297190522+1 LONE   .2623662130+3

 SMA   .7102677559+4 NODE   .1436722759+2   UX  -.936834634360 RPVX  -.298611596634 ALAT   .1555352233+3
 ECC   .2492721942-1  OMG   .3101622181+3   UY  -.1392643488-1 RPVY  -.602330999623  TAU   .5564836554+2
 INC   .5811462156+2    M   .2065976754+3   UZ   .351632231264 RPVZ  -.818750655162  PRD   .1005475128+3
 1/A   .890472165890    O  -.1138677109+1 APOG   .9801930949+3  PRG   .6088320240+3             ELLIPSE

 XVM  -.2117045582-6 XOVM  -.280206823741  XVS  -.5775121906+8 XOVS   .2545036831+2 OVPM   .4054099685+6
 YVM   .3086800048+6 YOVM  -.4665534266+1  YVS  -.1304840019+9 YOVS  -.1375467850+2 OVFS   .1516909170+9
 ZVM   .1557404160+6 ZOVM  -.5807315774+1  ZVS  -.5658063658+8 ZOVS  -.9831839156+1

     ORBIT PLANE SIGMA AND RHO MATRIX
         U              V              W             UDOT           VDOT           WDOT

         1              2              3              4              5              6
  1   .102552331
  2   .350524048     .270006738
  3   .1566134-1    -.1349959-1     .119330479
  4   .495374844     .963225281     .2375857-2     .2939818-3
  5   .999508962     .321958376     .1649129-1     .467967913     .1031432-3
  6   .4567822-2    -.1900244-1     .390448295    -.2606648-1     .5196508-2     .1118526-3

                                   EIGENVECTORS OF U,V,W COVARIANCE MATRIX
                .987420186                        .150229050                         .4932150-1
               -.150375207                        .988628710                        -.7550034-3
               -.4887404-1                       -.6671222-2                         .998782666

                                      SQUARE ROOTS OF THE EIGENVALUES
                .9532297-1                        .272729647                         .119371506

                                  TO ALIGN U,V,W WITH THE PRINCIPAL AXES
                                       YAW RIGHT          .3866 DEG
                                       PITCH DOWN       -8.6402 DEG
                                       ROLL CLOCKWISE    -2.8595 DEG

     POLAR SIGMA AND RHO MATRIX
       ALPHA          DELTA          BETA            AZ              R              V

         1              2              3              4              5              6
  1   .1526253-2
  2  -.649061810     .1815673-2
  3   .114040074    -.180733102     .6243601-3
  4   .360938586    -.472285940     .3637448-1     .9202624-3
  5  -.284108017     .341354521    -.630947840    -.170216800     .102552331
  6   .280288328    -.337561295     .630220978     .167772965    -.999987514     .1046531-3

     CARTESIAN SIGMA AND RHO MATRIX
         X              Y              Z             XDOT           YDOT           ZDOT

         1              2              3              4              5              6
  1   .101931296
  2   .233039790     .182921400
  3   .326884256     .653290951     .231970160
  4  -.333094239    -.827756510    -.924719358     .2645389-3
  5  -.455121182     .299883504     .132095729    -.266820570     .1077944-3
  6  -.148082864     .537624031     .829453749    -.750705255     .9616088-1     .1472555-3
```

4.3.2 INITIAL ORBIT DETERMINATION FROM ANGULAR FIXES - IOANGLE

4.3.2.1 Purpose

The IOANGLE program computes an element set describing a satellite orbit from three angular position fixes from the same sensor on the same revolution (e.g., telemetry data). The element set is then differentially corrected using additional observations.

4.3.2.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
	Job Card		
	Remarks Card		
	Program ID Card		
		1-6	SPSJØB
		9-15	IOANGLE
		17	0 = Parameter card, Observation cards and S-file tape inputs.
			2 = Parameter card, Observation cards and Sensor cards inputs
		18	0 = Hardcopy and punched cards output
		80	J = Card type
5	Parameter Card 1		
		1-3	Satellite number
		4-6	Element set number
		7	0 = Circular approximation only
			1 = Circular approximation and elliptical sector-to-triangle approximation
		8	0 = No differential correction
			1 = Differential correction
		9-18	Satellite name

Deck Position	Card Type	Column Number	Punch
		23-36	Epoch revolution (floating point)
		41-48	Minimum time between observations in the initial orbit computation
		80	P = card type
6	Parameter Card 2		
		24-36	Final revolution (floating point)
		67	0 = Correct the inclination
			1 = Do not correct the inclination
		80	P = Card type
6	End of Case Card		
7	End of Job Card		
8	End of Schedule Tape Card		
9	Blank Card		

4.3.2.3 Output

Program printout consists of four parts.

4.3.2.3.1 Part 1

The first part contains:

1. For each input observation; obs number, sensor identification, obs date, and observed angles.
2. Preliminary elements using the circular approximation input option:
   a. M12, the geocentric angle between the observations in radians
   b. semi-major axis in earth radii (A)
   c. inclination indegrees (INCL)
   d. node in degrees (NODE)
   e. period in minutes (P (MIN))
   f. a_{xn}, a_{yn} components (AXNO, AYNO)
   g. components of angular momentum vector (HXO, HYO, HZO)
   h. mean longitude in degrees (LO)

3. or, elements using first circular and then the sector-to-triangle method (input option):
   a. semi-major axis in earth radii (A)
   b. eccentricity (E)
   c. inclination in degrees (I)
   d. node in degrees (NODE)
   e. argument of perigee in degrees (OMEGA)
   f. time of nodal passage in minutes (TN)
   g. period in minutes (P (MIN))
   h. a_{xn}, a_{yn}, components (AXNO, AYNO)
   i. components of angular momentum (HXO, HYO, HZO)
   j. mean longitude (LO)

4.3.2.3.2 Parts 2-4

Parts 2-4 of the printed output contains the differential correction with further observations and corresponds to Parts 1-3 of the SGPDC program (see section 4.3.8.3).

SAMPLE PRINTOUT, IOANGLE

PART 1, CIRCULAR AND SECTOR-TO-TRIANGLE METHOD

INITIAL ORBITAL ELEMENT DETERMINATION FROM ANGLES ONLY

OBS.NO.	STAID	DATE OF OBSERVATION	OBSERVED ANGLES			
1	037	601209154019.189	26.6246	(DEC)	84.3161	(RA)
2	037	601209154040.211	42.2468	(DEC)	85.3891	(RA)
3	037	601209154057.463	54.7395	(DEC)	86.6212	(RA)

A	E	I	NODE	OMEGA	TN	P(MIN)
.112482849+1	.417429275-1	.815342411+2	.862679205+2	.790837232+2	.496300909+6	.10794406+3

OBS.NO	AXNO	AYNO	HXO	HYO	HZO	LO
2	.790484257-2	.409876256-1	.104588623+1	-.682224961-1	.15600063570	.125963077+3

PART 1, CIRCULAR METHOD

INITIAL ORBITAL ELEMENT DETERMINATION FROM ANGLES ONLY

OBS.NO.	STAID	DATE OF OBSERVATION	OBSERVED ANGLES			
1	029	640221015015.568	70.1501	(DEC)	328.5254	(RA)
2	029	640221014213.007	53.2261	(DEC)	236.2358	(RA)
3	029	640221013443.158	17.7143	(DEC)	220.1483	(RA)

M12	A	INCL	NODE	P(MIN)
.30424496281	.158593401+1	.872063115+2	.202875505+3	.168744448+3

OBS.NO	AXNO	AYNO	HXO	HYO	HZO	LO
1	.00000000000	.00000000000	-.48896101210	.115891486+1	.613798633-1	.280554359+3

SAMPLE PRINTOUT, IOANGLE

PART 2 INITIAL ORBIT ANGLES ONLY - DIFFERENTIAL CORRECTION APRIL 2, 1964 PAGE 5

SATELLITE NO. 000 SATELLITE NAME: SDC TESTOR ELEMENT SET NO. 0 TIME OF EPOCH 52.0517094

TAG NO.	STA NO.	TIME Y MM DD HH MM SS.SS	R R A J	RANGE RES, KM.	RT ASCEN RES, KM.	DECL. RES, KM.	AZIMUTH RES, KM.	ELEV. RES, KM.	RR. RES. KM./SEC.	VECTOR MAG. KM.	DELTA T MIN.	U DEG.	BETA DEG.
029	029	4 02 21 1 51 15.57	4		-.2173+2	.4779+2				.525+2	-.10	77	.1
029	029	4 02 21 1 42 13.01	4		-.4835+2	-.1496+2				.506+2	-.09	50	.1
029	029	4 02 21 1 34 43.15	4		-.3782+2	-.8067+1				.386+2	-.04	43	.2
029	029	4 02 21 1 49 36.90	4		-.3949+2	.4553+2				.602+2	-.13	75	.1
029	029	4 02 21 1 48 45.01	4		-.3876+2	.3745+2				.539+2	-.11	74	.1
029	029	4 02 21 1 44 48.57	4		-.5353+2	.1473+2				.555+2	-.11	69	.1
029	029	4 02 21 1 46 32.58	4		-.6392+2	.1360+2				.633+2	-.13	69	.1
029	029	4 02 21 1 45 52.57	4		-.5472+2	.5873+1				.550+2	-.10	67	.1
029	029	4 02 21 1 44 33.44	4		-.4904+2	-.6463+1				.494+2	-.10	65	.1
029	029	4 02 21 1 44 17.55	4		-.5280+2	-.5481+1				.530+2	-.10	64	.1
029	029	4 02 21 1 43 38.62	4		-.5259+2	-.1100+2				.537+2	-.10	63	.1
029	029	4 02 21 1 42 29.11	4		-.6679+1	-.1277+2				.144+2	-.03	50	-.0
029	029	4 02 21 1 41 38.22	4		-.4566+2	-.1497+2				.480+2	-.09	58	.1
029	029	4 02 21 1 39 53.88	4		-.4465+2	-.1793+2				.481+2	-.08	55	.1
029	029	4 02 21 1 37 22.72	4		-.4109+2	-.1597+2				.440+2	-.07	49	.2
029	029	4 02 21 1 35 40.71	4		-.3445+2	-.8958+1				.356+2	-.04	45	.1
029	029	4 02 21 1 35 24.71	4		-.3616+2	-.1237+2				.401+2	-.05	45	.1

PART 3 INITIAL ORBIT ANGLES ONLY - DIFFERENTIAL CORRECTION APRIL 2, 1964 PAGE 6

SATELLITE NO. 000 SATELLITE NAME: SDC TESTOR ELEMENT SET NO. 0 TIME OF EPOCH 52.0517094

CASE NO.	RMS KM.	RMS2 KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA UN	DELTA NODE	DELTA I	DELTA CO
0	.349598+2	.00000000	.38269991-2	-.11666-2	-.41818-2	-.43141-2	-.18790-2	.21956-2	

CORRECTED ELEMENTS

REV. NO.	CASE NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	CO DA/REV.2	PER ALT ST. MI.	PA MINUTES
	1	202.31606	52.05172	1.5643032	.00434	87.332	202.770	254.437	.0000000	2289.5	165.276

SAMPLE PRINTOUT, IOANGLE

PART 4 INITIAL ORBIT ANGLES ONLY - DIFFERENTIAL CORRECTION APRIL 2, 1964 PAGE 10

SATELLITE NO. 000 SATELLITE NAME: ST[illegible] ELEMENT SET NO. 0 TIME OF EPOCH 62.0989819

OLD RMS KM.	NEW RMS KM.	OLD RMS2 KM/SEC	NEW RMS2 KM/SEC	DELTA N/A	DELTA AXN	DELTA AYN	DELTA O	DELTA NODE	DELTA I	DELTA CO
.1404+3	.946+3	.00000	.00000	.15142096E-1						

NO. OF RESIDUALS USED = 8 NO. OF RESIDUALS REJECTED = 26

REV. NO.	SET NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	CC DA/REV**2	PER ALT ST. MI.	PA MINUTES
OLD ELEMENTS											
0	0	337.16034	92.04326	1.5889340	.00000	92.793	22.872	89.999	.0000000	2372.1	168.717
NEW ELEMENTS											
0	0	337.12877	81.91249	4.5915573	.00006	92.793	22.875	89.999	.0000000	14234.0	-31.253

NODE DOT = .000 DEG/DAY, OMEGA DOT = -.000 DEG/DAY

NO. OF ACCEPTABLE RESIDUALS LESS THAN NO. OF ELEMENTS BEING CORRECTED

ELEMENTS CORRECTED SUCCESSFULLY= A

ALL OBSERVATIONS WITHIN 60 MIN. OF EPOCH TIME

4.3.3 INITIAL ORBIT BY HERRICK-GIBBS - IOHG

4.3.3.1 Purpose

The IOHG program computes an element set describing a satellite orbit from three or more three-dimensional fixes from the same sensor on the same revolution (e.g., tracker data). The element set is then differentially corrected using additional observations.

4.3.3.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-12	IOHG
		17	0 = Parameter card, Observations cards and S-file tape inputs.
		18	0 = Hardcopy and punched cards output
		80	J - Card type
5	Program Card 1		
		1-3	Space Track number
		6	Element Set number
		8	1 = Corresponding Element card number
		9-18	Object name (optional)
		36	Epoch revolution
		79	1 = Second, next to last and median observations used in orbit computation
			2 = Third, second to last and median observations used in orbit computation
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
6	Parameter Card 2		
		8	4 = corresponding Element card number
		9-22	C-term
		80	P = Card type
7	Parameter Card 3		
		8	7 = Corresponding Element card number
		29	Initial revolution number
		36	Final revolution number
		67	0 = Correct all elements
			1 = Set the I-stop
			2 = Set the C-stop
			4 = Correct mean motion
		80	P = Card type
8	Data cards: a. Parameter card; b. Observation cards (min. = 3 from one sensor, in order of increasing time)		
9	End of Case Card		
10	End of Job Card		
11	End of Schedule Tape Card		
12	Blank Card		

4.3.3.3 Output

The program printout contains 4 parts.

4.3.3.3.1 Part 1

Part 1 contains the following information

1. Satellite name and number
2. Element set number
3. Time of epoch

4. SPACETRACK elements (initial orbit)
   a. Revolution number
   b. Semi-major axis, a (earth radii)
   c. Eccentricity, e
   d. Inclination, i (degrees)
   e. Node, Ω (degrees)
   f. Omega, ω (degrees)
   g. Drag, C_o (day/rev^2)
   h. Perigee altitude (statute mi.)
   i. Anomalistic period, Pa (min.)
5. $\underline{N}$, $\underline{M}$ elements
   a. Revolution number
   b. Mean longitude, L_o (radians)
   c. A_{xn}, A_{yn} components
   d. Angular momentum components (H_x, H_y, H_z)

4.3.3.3.2 Parts 2-4

Parts 2-4 of the printout correspond to parts 1-3 of the SGPDC printout (see section 4.3.8.3).

SAMPLE PRINTOUT, IOHG

PART 1 INITIAL ORBIT DETERMINATION, HERRICK GIBBS METHOD APRIL 1, 1964

SATELLITE NO. 369 SATELLITE NAME: H-I HG ELEMENT SET NO. 3 TIME OF EPOCH: 345.2015333

SPACE TRACK ELEMENTS

REV NO.	A EARTH RADII	E	I DEGREES	NODE DEGREES	OMEGA DEGREES	OO DAY/REV**2	PER ALT ST. MI.	PA MINUTES
0	1.04752502	.099867	101.3478	313.1414	344.4548	-.38599999-9	-83.29758	95.6800

VARIATION OF PARAMETER ELEMENTS

REV NO.	LC RADIANS	AXNO E*COS(OMEGA)	AYNO E*SIN(OMEGA)	HXO EARTH RADII	HYO EARTH RADII	HZO EARTH RADII
	.244194941+1	.969901141-1	-.235452739-1	-.74232934985	-.69560717514	-.20417151233

SAMPLE PRINTOUT, IOHG

PART 2 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION APRIL 1, 1964 PAGE 1

SATELLITE NO. 369 SATELLITE NAME H-I HG ELEMENT SET NO. 3 TIME OF EPOCH 345.2015339

TAG NO.	STA NO.	Y	MM	DD	HH	MM	SS.SS	R A	R J	RANGE RES, KM.	RT ASCEN RES, KM.	DECL. RES, KM.	AZIMUTH RES. KM.	ELEV. RES, KM.	RR. RES. KM./SEC.	VECTOR MAG, KM.	DELTA T MIN.	U DEG.	BETA DEG.
369	128	3	12	11	4	51	59.00	1	+	.7201+2			-.5984+2	-.1284+3	.651712+	.174+3	-.00	99	1.1
369	328	3	12	11	4	50	36.48	2	+	.797345			-.2724+1	.8892+1	.743286+	.918+1	-.00	94	+.0
369	328	3	12	11	4	50	12.54	1	+	.2569+1			-.3194+1	.5955+1	.772385+	.747+1	-.00	92	.0
369	329	3	12	11	4	45	18.22	1	+	-.2347+3			-.1434+3	.3533+3	.629979+	.534+3	.36	75	-3.1
369	328	3	12	11	4	43	30.15	1	+	-.2968+3			-.2663+3	.5454+3+	.510482+	.716+3	.29	68	-4.2
369	329	3	12	11	4	42	54.87	1	+	-.3003+3			.3097+3	.6434+3+	.1075+1+	.807+3	.34	66	-4.7
369	329	3	12	11	4	42	24.95	1	+	-.3524+3			.2961+3	.6185+3+	.1097+1+	.840+3	.36	65	-4.9

PART 3 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION APRIL 1, 1964 PAGE 2

SATELLITE NO. 369 SATELLITE NAME H-I HG ELEMENT SET NO. 3 TIME OF EPOCH 345.2015339

CASE NO.	RMS KM.	RMS2 KM/SEC	DELTA N/A	DELTA AXN	DELTA AYN	DELTA UO	DELTA NODE	DELTA I	DELTA CD
1	.712450+3	.00000000	-.43973227-4						

CORRECTED ELEMENTS

REV. NO.	CASE NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	CD DA/REV..2	PER ALT ST. MI.	PA MINUTES
0	1	44.42038	345.18309	1.1196400	.09980	101.347	343.116	349.435	-.41994.9	31.2	100.067

SAMPLE PRINTOUT, IOHG

PART 4 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION APRIL 1, 1964 PAGE 17

SATELLITE NO. 347 SATELLITE NAME: B-I HG ELEMENT SET NO. 3 TIME OF EPOCH 345.1817930

OLD RMS KM.	REJ RMS KM.	OLD RMS2 KM/SEC	NEW RMS2 KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA LO	DELTA NODE	DELTA I	DELTA CO
.269+3	.565+1	.231+0	.146-1	.34527851-3	.43570-3	-.16837-7	-.66087-3	.41935-4	-.15964E-4	

NO. OF RESIDUALS USED = 25 NO. OF RESIDUALS REJECTED = 3

REV. NO.	SET NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	CC DAY/REV**2	PER ALT ST. MI.	PA MINUTES
OLD ELEMENTS											
0	3	14.42551	345.18368	1.0875250	.09980	101.347	313.145	346.408	-.3859929	-83.2	95.791
NEW ELEMENTS											
0	3	13.77821	345.18379	1.1050636	.02502	98.630	323.522	253.545	-.3838129	306.7	98.117
NEW ELEMENTS											
15	4	32.74617	346.20346	1.1050634	.02502	98.630	324.602	250.354	-.3838129	306.7	98.117

NODE DOT = 1.056 DEG/DAY, OMEGA DOT = -3.120 DEG/DAY

ALL ELEMENTS CORRECTED IN FIRST ATTEMPT

ELEMENTS NOT REPLACED, MANUAL RUN

4.3.4 INITIAL ORBIT DETERMINATION FROM INDEPENDENT RADAR FIXES - IORF

4.3.4.1 Purpose

The IORF program computes an element set describing a satellite orbit from two or more radar fixes, which may come from different stations or occur during different revolutions. The element set is then differentially corrected using additional observations.

4.3.4.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-12	IORF
		17	0 = Parameter card, Observation cards and S-file tape inputs.
			2 = Parameter card, Observation cards and Sensor cards inputs.
		18	0 = Hardcopy and punched cards output
		80	J = Card type
5	Parameter Card 1		
		1-3	Satellite number
		4-6	Element set number
		9-18	Satellite name
		23-36	Epoch revolution
		79	0 = No differential correction
			1 = Differential correction
		80	P = Card type

NOTE: All inputs are right-adjusted.

Deck Position	Card Type	Column Number	Punch
6	Parameter Card 2		
		9-22	Drag term, C_0 (days); if unknown, use zero
		23-24	M, maximum number of solutions desired
		24-36	ε_3 (min.), magnitude of the difference between the computed and observed times between the two positions.
		37-48	ε_4 (km.), distance of the third position fix from the computed orbit
		49-60	m, number of parts into which to divide the interval between minimum ρ and maximum ρ
		80	P = Card type

NOTE: If blank, the program assumes M = 1.0, ε_3 = .001 min., ε_4 = 100km. and m = 50.

7	Parameter Card 3		
		23-36	Predicted revolution number (see DC output)
		67	0 = Correct the inclination 1 = Do not correct the inclination
		80	P = Card type

8 Data Cards:

- a. Input Option 0:
  - (1) Observation cards
- b. Input Option 2:
  - (1) Observation cards
  - (2) Sensor cards

9 End of Case Card

10 End of Job Card

11 End of Schedule Tape Card

12 Blank Card

4.3.4.3 Output

Printout of this program contains 4 parts.

4.3.4.3.1 Part 1

The first part contains:

1. Observations to be used
   a. observation numbers
   b. time of observations to thousandths of seconds
   c. x, y, z and r in earth radii
2. Initial elements
   a. semi-major axis in earth radii
   b. eccentricity
   c. inclination in degrees
   d. node in degrees
   e. omega in degrees
   f. T_n, time of first node after T_1, days since 1950
   g. L_1, longitude of first observation in degrees
   h. a_{xn}, a_{yn},
   i. angular momentum components (H_x, H_y, H_z)
   j. T_1, time of first observation, days since 1950
   k. revolutions between observations
   i. perifocal distance (q) earth radii
   l. semi-latus rectum (p) earth radii
   m. mean angular motion ($\varkappa$) radians/min
   n. a drag coefficient (c")

4.3.4.3.2 Parts 2-4

Parts 2-4 of the printout correspond to parts of the SCPDC printout (see section 4.3.8.3).

SAMPLE PRINTOUT, IORF

```
PART 1        INITIAL ORBIT DETERMINATION, P-ITERATION METHOD                DECEMBER 17, 1963   PAGE 1

    THE OBSERVATIONS TO BE USED ARE -
     OBS NO    YMMDDHH MMSS.SSS      X-RADII            Y-RADII            Z-RADII            R-RADII
     23041    63120904 2730.283   .43363592762036   -.51785167591081   .90689245663818   .11307904402 8+1
     23051    63120904 2957.548   .31343363015914   -.44051713967730   .97479855 31578   .113457571482+1
     23053    63120904 3049.335   .26800316415030   -.41107201913039   .102054950373+1   .113239886530+1

       A-RADII              E             I-DEGREES         NODE-DEGREES      OMEGA-DEGREES    TN-DAYS SINCE 1950
    .110577082 3/7+1   .331410205923-1   .986417119274+2   .321714522-65+3   .279806112404+3   .509124353469+4
      L1-DEGREES            AXN              AYN               HX                 HY               HZ
    .897377112647+2    .504440072979-2   -.326568214513-1   -.643744522 8928   -.815605410056 9   -.157914964972
  T1-DAYS SINCE 1950  REVS BETWEEN OBS      Q-RADII           P-RADII        N-RADIANS/MIN   C DBL PRIME-1/MINS
    .509118576650+4          0          .106912445044+1   .110455622-59+1   .639551046846-1   .00000000000002
    MAGNITUDE OF DELTA R BAR = .2355484+2 KMS, THEREFORE 3RD OBSERVATION DOES FIT THIS ORBIT
```

SAMPLE PRINTOUT, IORF
DIFFERENTIAL CORRECTION

PART 2 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION DECEMBER 17, 1963 PAGE 1

SATELLITE NO. SATELLITE NAME: 369 IORF ELEMENT SET NO. 222 TIME OF EPOCH 343.1857668

TAG NO.	STA NO.	Y	MM	DD	HH	MM	SS.SS	R A	R J	RANGE RES. KM.	RT ASCEN RES. KM.	DECL. RES. KM.	AZIMUTH RES. KM.	ELEV. RES. KM.	RR. RES. KM./SEC.	VECTOR MAG. KM.	DELTA T MIN.	J DEG.	BETA DEG.
369	329	3	12	09	4	27	30.28	1		.6293-1			-.134228	-.3840-1	-.9847-1	.16556	-.00	51	-.0
369	329	3	12	09	4	29	57.55	1		-.8067-1			.1166+1	.6336-1	-.9131-1	.117+1	.00	60	.0
369	329	3	12	09	4	30	49.34	1		-.1830+1			-.1222+1	-.2347+2	-.8082-1	.236+2	-.00	63	.0
369	329	3	12	09	4	34	42.09	1		-.5352+1			.1657+2	-.4238+2	-.6343-3	.461+2	.05	77	.0
369	328	3	12	09	9	33	19.87	1	*	.1232+4*			-.3771+3	-.6333+3*	-.1070+1*	.180+4	-3.61	78	.1
369	328	3	12	09	9	34	11.96	1	*	.1163+4*			-.4242+3	-.6380+3*	-.1626+1*	.181+4	-3.59	81	.0
369	328	3	12	09	11	12	50.43	1	*	.1612+4*			-.6694+2	-.7967+3*	-.2454+1*	.241+4	-4.82	78	.0

PART 3 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION DECEMBER 17, 1963 PAGE 2

SATELLITE NO. SATELLITE NAME: 369 IORF ELEMENT SET NO. 222 TIME OF EPOCH 343.1857668

CASE NO.	RMS KM.	RMS2 KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA UO	DELTA NODE	DELTA I	DELTA CO
0	.147976+3	.783744-1	-.11066680-1						

CORRECTED ELEMENTS

REV. NO.	CASE NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	DO DA/REV**2	PER ALT ST. MI.	PA MINUTES
5555	1	34.63437	343.17519	1.1140049	.03314	95.641	321.705	279.838	.5000000	305.5	99.403

SAMPLE PRINTOUT, IORF

PART 4 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION DECEMBER 17, 1963 PAGE 11

SATELLITE NO. SATELLITE NAME: 369 IORF ELEMENT SET NO. 222 TIME OF EPOCH 343.1857668

OLD RMS KM.	NEW RMS KM.	OLD RMS2 KM/SEC	NEW RMS2 KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA UO	DELTA NODE	DELTA I	DELTA CO
.313+3	.306+1	.783-1	.488-2	.40525382-8	-.80734-7	.503-3-7	.19947-6	.25437-7	.53593-8	

NO. OF RESIDUALS USED = 24 NO. OF RESIDUALS REJECTED = 4

REV. NO.	SET NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	CO DA/REV**2	PER ALT ST. MI.	PA MINUTES
OLD ELEMENTS											
5555	222	34.63552	343.17530	1.1057708	.03314	98.541	121.705	279.838	.0000000	273.9	98.304
NEW ELEMENTS											
5555	222	36.75716	343.17515	1.1149223	.01608	98.466	121.558	251.075	.0000000	384.3	99.526
NEW ELEMENTS											
5560	223	36.41323	343.32093	1.1149223	.01608	98.466	121.913	250.032	.0000000	384.3	99.526

NODE DOT = 1.026 DEG/DAY, OMEGA DOT = -3.018 DEG/DAY

ALL ELEMENTS CORRECTED IN FIRST ATTEMPT

ELEMENTS NOT REPLACED, MANUAL RUN

4.3.5 LOCKHEED VECTOR COORDINATES - LOCVEC

4.3.5.1 Purpose

The LOCVEC program computes the predicted position and velocity of a satellite for the Satellite Control Facility (SCF) from a seven-card element set. The output is a special binary teletype tape which is used as an input to the CDC computer at SCF.

4.3.5.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-30	LOCVEC
		31-35	,DATA
5	Request Card (max. = 500, requires one for each element set)		
		1-3	SPADATS object number (optional)
		9	First digit of STC* satellite number, or 9 = SPADATS number used
		10-12	Satellite number (last two digits)
		13-20	Satellite name
		21-24	Country of origin
6	End Request Deck Card		
		8	Any of the digits 1-9
7	Element Set Cards (max. = 500 sets)		
8	Blank Card		
9	End of Data Card		
10	End of Job Card		
11	End of Schedule Tape Card		
12	Blank Card		

* Sunnyvale Track Center ≈ Satellite Control Facility

4.3.5.3 Output

There are two output lines printed for each satellite. The order is the same as that of the request deck. Each line contains:

1. Satellite number
2. Sunnyvale Tracking Center number, or if preceded by 9, the SPACETRACK number
3. Element number
4. Month, day, hour of epoch
5. Seconds since start of epoch month
6. Epoch revolution
7. x, y, z coordinates in feet
8. Velocity components in feet per second

SAMPLE PRINTOUT, LOCVEC

```
VECTOR COORDINATES FOR LOCKHEED
SAT  STC ELE MO DA HR    ELAPSEC REV          X/XDOT          Y/DOT          Z/DOT    FT/FT/SEC
 116 9116  37  /  1  4 102553.937       5090     6965570.16     -22782710.69       1262.08
                                             9148.18          2930.80        22426.22
```

4.3.6 RADAR ORBIT COMPUTATION - ROC

4.3.6.1 Purpose

The ROC program computes an initial orbit from a radar track or from geocentric rectangular coordinates and velocities. There is no differential correction of the computed element set.

4.3.6.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-27	ROC
		28-32	,DATA
5	Parameter Card		
		1-3	Number (odd) of observation cards to be input (from 3-999); required only for input option 1
		6-17	Satellite name
		18-35	Date of computation
		41	1 = Element cards output
		42	1 = print x, y, z, $\dot{x}$, $\dot{y}$ and $\dot{z}$ for the mean of the observations
6	Data Cards:		

a. Input Option 1:
   (1) Sensor cards
   (2) Observation cards

b. Input Option 2:
   (1) Rectangular Coordinate cards
   1-14 x (km.), including decimal point
   15-28 y (km.), including decimal point

Deck Position	Card Type	Column Number	Punch
		29-42	z (km.), including decimal point
		43-46	Year of epoch
	(2)	Velocity Component cards	
		1-14	$\dot{x}$ (km./sec.), including decimal point
		14-28	$\dot{y}$ (km./sec.), including decimal point
		29-42	$\dot{z}$ (km./sec.), including decimal point
		43-56	Day of year of observation (in days and fractions), including decimal point
7	End Card		
		79	9 = Card type
8	End of Data Card		
9	End of Job Card		
10	End of Schedule Tape Card		
11	Blank Card		

4.3.6.3 Output

Program printout consists of the normal Radar Orbit Computation plus one extra option.

4.3.6.3.1 Normal Printout

The normal printout contains:

1. Satellite name and number.
2. Semi-major axis (km and earth radii).
3. Period (P_n in days).
4. Perigee and apogee (in km and earth radii).
5. Right ascension of ascending node (deg.)
6. Argument of perigee (degrees).
7. Time of last perigee pass (days).
8. Time of last nodal crosing (days).
9. Radius vector (km).
10. Velocity (km/sec).
11. Inclination (degrees).
12. Eccentricity (e) and e^2.

4.3.6.3.2 Optional Output

The optional printout contains the geocentric rectangular coordinates (x, y, z) and the velocity components with the time of the observation.

SAMPLE PRINTOUT, ROC

RADAR ORBIT COMPUTATION 00000000000000000000

SATELLITE: 719 80 LVROC SATELLITE NO. 800

THE BELOW INFORMATION COMPUTED FOR 13 FEB 1964

SEMI-MAJOR AXIS	PERIOD	PERIGEE	APOGEE
KM	DAYS	KM	KM
6730.136334000	0.063909909	315.789159900	388.219911400
EARTH RADII	MINUTES	EARTH RADII	EARTH RADII
1.055102364	91.978100990	1.049495361	1.060866247
RIGHT ASCENSION	ARGUMENT OF PERIGEE	TIME OF PERIGEE	TIME OF NODE
DEGREES	DEGREES	DAYS	DAYS
300.310329900	73.281650010	44.207810000	44.258075190
RADIUS VECTOR	VELOCITY	INCLINATION	
KM	KM/SEC	DEGREES	
6719.492393000	7.708106079	44.914181350	
ECCENTRICITY	ECCENTRICITY SQUARE		
0.005086690	0.000029016		

4.3.7 SEAI TAPE FILE MAINTENANCE - SEAI

4.3.7.1 Purpose

The SEAI program generates a new SEAI tape or modifies an existing SEAI tape by replacing, adding or deleting data.

4.3.7.2 Input - Schedule Tape Mode (Toggle 24 On)

The SEAI program may be run in the Regular or the Special input mode. The Special input mode is used exclusively to add an element set to the SEAI files on a foreign launch. Toggle 47 On = Build new SEAI tape. Toggle 47 Off = Update old SEAI tape.

4.3.7.2.1 Regular Input Mode (Toggle 44 Off)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-28	SEAI
		29-33	,DATA
5	Sensor Card (optional)		
6	Element Set Cards (optional)		
7	Acquisition Card (optional)		
8	Information Card (optional)		
9	Delete Card (optional)		
10	End Card		
		1-3	END
11	End of Data Card		
12	End of Job Card		
13	End of Schedule Tape Card		
14	Blank Card		

4.3.7.2.2 Special Input Mode (Toggle 44 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-28	SEAI
		29-33	,DATA
5	Parameter Card		
		1	U, Blank = Unclassified
			E = Unclassified EFTO
			C = Confidential
			F = Confidential/NoForn
			S = Secret
			N = Secret/NoForn
		2	D = Deferred
			R = Routine
			P = Priority
			O = Immediate
			Z = Flash
		3	K = Launch area
			T, Blank = Launch area
		4	Z = Send flash bulletin to DIA/CIIC

NOTE: Used only when launch deviates from nominal inclination by 5 degrees or more, or when launch area appears to be other than K or T.

		5	T, Blank = Transmitting
			N = Non-transmitting
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
6	Element Set Cards		
7	End Card		
		1-3	END
8	End of Data Card		
9	End of Job Card		
10	End of Schedule Tape Card		
11	Blank Card		

4.3.7.3 Output

No printed output is generated by this program except for rejected input cards.

4.3.8 SIMPLIFIED GENERAL PERTURBATIONS EMPHEMERIS WITH DIFFERENTIAL CORRECTION - SGPDC

4.3.8.1 Purpose

The SGPDC program computes the best fitting orbit (in the least squares sense) to a set of observations. All or any of the six elliptical elements and the drag parameter may be corrected. The program converges on as many parameters as possible.

4.3.8.3 Input

4.3.8.2.1 Automatic Mode - in an OCS sequence

a. Observations from the SRADU tape.
b. Sensor coordinates from the S-file tape.
c. Satellite numbers from the SATTB tape.
d. Corresponding element sets from the E-file tape.
e. OCS Toggle number = Desired OCS sequence.

4.3.8.2.2 Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-13	SGPDC
		17	0 = Satellite Number cards, S-file, E-file and SRADU tape inputs
			1 = Satellite Number and Observation cards and S-file and E-file tape inputs
			2 = Observation Number and Element Set cards and S-file and SRADU tape inputs
			3 = Element Set and Observation cards and S-file tape inputs.

NOTE: When using Element Set Cards: cols. 23-36 of the 7th card should be blank and col. 67 of the 7th card should specify the desired correction. When using the E-file tape: +, -, E or N must be input by flexowriter.

Deck Position	Card Type	Column Number	Punch
			4 = Satellite Number and Observation Number cards and S-file, E-file and SRADU tape inputs
		18	0 = Hardcopy and punched cards output
			1 = Angle residuals in degrees
		80	J = Card type
5	Data Cards:		
	a. Input Option 0:		
	Satellite Number cards		
	b. Input Option 1:		
	Satellite Number cards		
	Observation cards		
	c. Input Option 2:		
	Observation Number cards		
	Element Set cards		
	d. Input Option 3:		
	Element Set cards		
	Observation cards		
	e. Input Option 4:		
	Satellite Number cards		
	Observation Number cards		
6	End of Case Card		
7	End of Job Card		
8	End of Schedule Tape Card		
9	Blank Card		

4.3.8.3 Output

Printout from the program contains three separate parts.

4.3.8.3.1 Part 1

The first part is the differential correction residuals and contains the following quantities for each case:

1. Tag and sensor number
2. Time of observation to hundredths of seconds
3. Association status (RA)
4. Rejection indicator (RJ) - asterisk indicates rejection of at least one residual. The residual rejected will appear with an asterisk also.
5. Range residuals (km)
6. Right ascension and declination residuals (km.) or azimuth
7. Elevation residuals (km.)
8. Range rate residual (km/sec)
9. Vector magnitude (km.)
10. Delta t (minutes)
11. Mean latitude (u)
12. Out-of-plane angle (BETA)

4.3.8.3.2 Part 2

Part 2 contains corrective quantities and elements as follows:

1. RMS and RMS2
2. $\Delta\kappa/\kappa$ (mean angular velocity)
3. Δa_{xn}, Δa_{yn} (components of $\underline{a}$)
4. ΔU, (mean latitude)
5. Changes in node, inclination and drag term
6. Corrected elements (if they are corrected) revolution number, case number, L, To, a, e, i, Ω, ω, C_o, perigee altitude, P_A.

4.3.8.3.3 Part 3

Part 3 is a summary sheet which contains in addition to a printout like Part 2 old RMS values, old elements, rate of change of omega and node, and summary notes.

SAMPLE PRINTOUT, SGPDC

PART 1

SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION FEBRUARY 27, 1964 PAGE 1

SATELLITE NO. 728 SATELLITE NAME: 1964-1B ELEMENT SET NO. 5 TIME OF EPOCH 43.7140903

TAG NO.	STA NO.	Y	MM	DD	TIME HH	MM	SS.SS	R A	R J	RANGE RES. KM.	RT ASCEN RES. KM.	DECL. RES. KM.	AZIMUTH RES. KM.	ELEV. RES. KM.	RR, RES. KM./SEC.	VECTOR MAG. KM.	DELTA T MIN.	J DEG.	BETA DEG.
728	329	4	02	23	14	26	14.30	1	*	-.3984+0			.1959+1	.3950+2*	-.4918+2	.395+2	.01	125	.1
728	328	4	02	22	18	56	47.93	1	*	-.4140+1			.1670+2	.3923+2*	-.4181-1*	.428+2	.04	83	.1
728	329	4	02	22	15	41	46.43	2	*	-.7907+1			.5909+1	.3685+2*	-.8346+2	.381+2	.01	118	.1
728	329	4	02	22	15	41	13.30	2	*	-.8146+1			.6690+1	.3205+2*	-.7035+2	.337+2	.01	116	.1
728	329	4	02	22	15	40	35.73	2	*	-.4129+1			.635078	.3655+2*	-.3592+2	.367+2	-.00	114	.1
728	330	4	02	22	15	20	20.24	1		-.4605+1			.1435+2	-.5269+1	-.2575-1	.159+2	.03	43	.0
728	340	4	02	22	9	1	49.96	1	*	-.2396+2*			-.1204+2	.5289+1		.270+2	-.24	166	.1
728	340	4	02	22	9	1	39.97	1	*	-.2316+2*			-.1429+2	.6703+1		.280+2	-.05	166	.0
728	340	4	02	22	9	1	30.00	1	*	-.3041+2*			-.1655+2	.6338+1		.352+2	-.06	165	.1
728	340	4	02	22	9	1	19.97	1	*	-.2899+2*			-.1651+2	.1025+2		.332+2	-.06	165	.1
728	340	4	02	22	9	1	10.00	1	*	-.2812+2*			-.1321+2	.5653+1		.325+2	-.03	164	.1
728	340	4	02	22	7	16	39.96	1		-.1430+2			.1636+2	-.836075		.217+2	-.03	161	-.0
728	340	4	02	22	7	16	29.99	1		-.1616+2			.1511+2	.1864+1		.222+2	-.03	160	-.0
728	328	4	02	21	20	34	13.75	1	*	-.1614+2			.1309+2	.2198+2*	-.3417-1*	.302+2	.05	85	.1
728	328	4	02	21	20	34	13.65	2		-.1587+2			.5991+1	.2183+2	-.3106-1	.276+2	.03	85	.1
728	329	4	02	21	15	35	40.09	1		-.9190+1			.1556+1	.1746+2	-.9554+2	.197+2	.01	127	.1
728	329	4	02	21	15	29	28.81	1	*	-.9084+1			-.4369+1	.2876+2*	-.3061+2	.304+2	-.02	105	.1
728	329	4	02	21	15	29	27.36	1	*	-.1579+1			-.1047+2	.3084+2*	-.6302-1*	.326+2	-.03	105	.0
728	328	4	02	18	9	48	50.30	1		-.1175+2			.354608	.1758+2	-.1310-1	.211+2	-.02	90	.1
728	329	4	02	17	16	41	25.61	1	*	-.7758+1			.476308	.2235+2*	.5161-2	.236+2	-.00	116	.1
728	042	4	02	17	1	19	17.81		*		-.2576+2*	.1893+2				.319+2	.06	147	-.1
728	329	4	02	16	16	36	8.93	2	*	-.8053+1			-.8368+1	.2908+2*	.1076-1	.313+2	.00	128	.1
728	329	4	02	12	17	43	1.03	2	*	-.8171+1			.9457+1	.3738+2*	-.2005-1	.394+2	.02	120	.1
728	329	4	02	12	17	42	9.86	1		-.6560+1			.5560+1	.1610+2	-.2318-1	.182+2	.01	118	.1
728	329	4	02	12	17	41	22.22	1		-.8550+1			.3901+1	.1394+2	-.1874-1	.168+2	.00	115	.1
728	785	4	02	10	12	42	27.36	4					-.4125+1	.6530+1		.772+1	-.01	215	.0
728	329	4	02	10	12	1	9.98			-.1753+1			-.1115+2	-.8589+1	-.2179-1	.141+2	.01	71	-.0

PART 2

SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION FEBRUARY 27, 1964 PAGE 3

SATELLITE NO. 728 SATELLITE NAME: 1964-1B ELEMENT SET NO. 5 TIME OF EPOCH 43.7140903

CASE NO.	RMS KM.	RMSE KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA UO	DELTA NODE	DELTA I	DELTA C"
0	.84747+1	.122028-1	.90260086-7						

SAMPLE PRINTOUT, SGPDC

PART 3 SIMPLIFIED GENERAL PERTURBATION DIFFERENTIAL CORRECTION FEBRUARY 27, 1964 PAGE 6

SATELLITE NO. 728 SATELLITE NAME: 1964-10 ELEMENT SET NO. 5 TIME OF EPOCH 56.5765872

OLD RMS KM.	NEW RMS KM.	OLD RMS2 KM/SEC	NEW RMS2 KM/SEC	DELTA N/N	DELTA AX	DELTA AYN	DELTA MO	DELTA NODE	DELTA I	DELTA C*
.145+2	.631+1	.227-1	.122-1	.90260086-7						

NO. OF RESIDUALS USED = 209 NO. OF RESIDUALS REJECTED = 38

REV. NO.	SET NO.	L DEGREES	TO DAYS	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	CO DA/REV**2	PER ALT ST. MI.	PA MINUTES
OLD ELEMENTS 444	5	58.50614	43.71409	1.1441825	.00193	69.934	58.451	14.153	-.28581-9	543.3	103.448
OLD ELEMENTS 623	6	31.09274	56.57658	1.1441814	.00193	69.934	31.019	357.715	-.28581-9	542.6	103.448
NEW ELEMENTS 623	4	31.01084	56.57657	1.1441813	.00193	69.934	31.019	357.715	-.28581-9	542.6	103.448

NODE DOT = -2.132 DEG/DAY, OMEGA DOT = -1.278 DEG/DAY

INITIAL REVOLUTION FOR NEXT BULLETIN IS 655

ALL ELEMENTS CORRECTED IN FIRST ATTEMPT

ELEMENTS NOT REPLACED, MANUAL RUN

4.3.9 SPIRAL DECAY - SPIRDECB

(The input and output information for the SPIRDECB program will be included in this document when the program becomes operational.)

4.3.10 SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION - SPWDC

4.3.10.1 Purpose

The SPWDC program corrects a given element set and computes predicted satellite positions. The differential correction is accomplished using a least square fit of observations which have been weighted by the Observation Weighting program (OBSWGT). The emphemeris and prediction computations use a special perturbations variation of parameters formulation. This requires that only the perturbations in the elements be integrated at each integration step instead of the whole force field as is required by an Encke method. All integrations are numerical and can take place in either a backward or forward direction. The perturbations included are:

a. Earth Bulge
b. Drag (1962 NASA atmosphere)
c. Radiation pressure

There are two types of prediction:

a. By time in which the start time, number of points and time between points are specified.
b. By station pass, in which a closest point of approach (CPA) point and points on either side of the CPA point are computed.

4.3.10.2 Input - Schedule Tape Mode Only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-14	OBSWGT
		17	0 = Parameter cards, Satellite Number cards, and S-file, E-file and SRADU tape inputs.

Deck Position	Card Type	Column Number	Punch
		17 (cont'd)	1 = Parameter cards, Element Set cards, and S-file and SRADU tape inputs
			2 = Parameter cards, Satellite Number cards, Sensor cards, and E-file and SRADU tape inputs
			3 = Parameter cards, Sensor cards, Element set cards and SRADU tape inputs
			4 = Parameter cards, Observation cards, Satellite Number cards, and S-file and E-file tape inputs
			5 = Parameter cards, Observation cards, Element Set cards and S-file tape inputs
			6 = Parameter cards, Observation cards, Sensor cards, Satellite Number cards and E-file tape inputs
			7 = Parameter cards, Observation cards, Sensor cards and Element Set cards inputs
			8 = Parameter cards, Element Set cards and S-file tape inputs
			9 = Parameter cards, Satellite Number cards, and S-file and E-file tape inputs
		18	0 = Hardcopy and punched cards output
5	OBSWGT Parameter Card		
		1-5	SPWDC
		9-11	Satellite number (optional)
		12	0, Blank = Weighting Tape input
			1 = Use Sensor Weighting Data in OBSWGT Weight file
		79	0, Blank = Use Observation weights in SPWDC
			1 = Do not use observation weights in SPWDC
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
6	Vehicle Characteristic Card (required only for DC option)		
		1-42	Remarks
		43-52	Diameter of Satellite (in meters)
		53-62	Mass of satellite (in kilograms)
		63-72	Reflectivity
		79	2 = Parameter card number
		80	P = Card type

NOTE: If the Vehicle Characteristic card is omitted, the program assumes Mass = 10.0 kg., Diameter = 1.0 meters and Reflectivity = 1.0.

Deck Position	Card Type	Column Number	Punch
7	Differential Correction Parameter Card (required only for DC)		
		1	Blank = Variable Δt integration
			1 = Fixed Δt integration
		2-11	Delta t (min.), plus (+) or minus (-)
		12	0 = Do not compute bulge perturbation
			1 = Compute bulge perturbation
		13	0 = Do not compute drag perturbation
			1 = Compute drag perturbation
		14	0 = Do not compute radiation pressure perturbation
			1 = Compute radiation pressure perturbation
		15	0, Blank = New epoch is revolution in cols. 16-29 of this card
			1 = New epoch is time in cols. 16-29 of this card
			2 = New epoch is time of last observation
		16-29	Time (days) since 1 Jan., or
			Absolute revolution number, or
			Blank if col. 15 of this card has a 2 punch
		30	0, Blank = Do not correct n
			1 = Correct n

Deck Position	Card Type	Column Number	Punch
7 (Cont'd)		31	0, Blank = Do not correct a_{xN}
			1 = Correct a_{xN}
		32	0, Blank = Do not correct a_{yN}
			1 = Correct a_{yN}
		33	0, Blank = Do not correct U_0
			1 = Correct U_0
		34	0, Blank = Do not correct Ω
			1 = Correct Ω
		35	0, Blank = Do not correct i
			1 = Correct i
		36	0, Blank = Do not correct m
			1 = Correct m
		37	Maximum number of correction
		38	0, Blank = n is not the only first pass correction
			1 = n is the only first pass correction
		39	0 = No Δq check
			1 = Δq check

NOTE: Cols. 38 and 39 are used only if 6 or 7 elements are corrected.

Deck Position	Card Type	Column Number	Punch
		40-47	Maximum Δq (km.)
		48-55	Absolute maximum azimuth, elevation and range residuals (in kilometers)
		56-63	Absolute maximum range rate residual (in kilometers/second)
		64-71	RMS multiplier
		72	0, Blank = No residual output
			1 = First and last residual output
			2 = All residuals output
		79	3 = Parameter card number
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
8	Absolute Error Parameter Card		
		1-10	a_L (Absolute Error criteria)
		11-20	a_{a_x}
		21-30	a_{a_y}
		31-40	a_{a_z}
		41-50	a_{h_x}
		51-60	a_{h_y}
		61-70	a_{h_z}
		79	4 = Parameter card number
		80	P = Card type

NOTE: If the Absolute Error card is omitted, the program assumes $a_L = 10^{-7}$, $a_{\underline{a}} = a_{\underline{h}} = 10^{-8}$

Deck Position	Card Type	Column Number	Punch
9	Relative Error Parameter Card		
		1-10	r_L (Relative Error criteria)
		11-20	r_{a_x}
		21-30	r_{a_y}
		31-40	r_{a_z}
		41-50	r_{h_x}
		51-61	r_{h_y}
		61-70	r_{h_z}
		79	5 = Parameter card number
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
10	Time Prediction Parameter Card 1 (Prediction-by-time option only)		
		1	Blank = Variable Δt integration
			1 = Fixed Δt integration
		2-11	Delta t (min.); plus (+) or minus (-)
		12	0 = Do not compute bulge perturbation
			1 = Compute bulge perturbation
		13	0 = Do not compute drag perturbation
			1 = Compute drag perturbation
		14	0 = Do not compute radiation pressure perturbation
			1 = Compute radiation pressure perturbation
		16	Print option - sum the desired options:
			1 = Print t, $\underline{r}$, $\dot{\underline{r}}$
			2 = Print t, a, e, i, Ω, ω, U
			4 = Print T, ϕ, λ_E, h
		17	0, Blank = No binary tape output
			1 = Binary tape output
		18	0, Blank = Do not compute prediction reliability
			1 = Compute prediction reliability (must have weighted 6 or 7 element DC including the drag term)
		19	0, Blank = Do not punch $\underline{r}$, t
			1 = Punch $\underline{r}$, t
		79	6 = Parameter card number
		80	P = Card type
11	Time Prediction Parameter Card 2 (Prediction-by-time option only)		
		1-12	Time (in days) since 1 Jan.
		13-20	Delta t (min.)
		21-24	Number of output points
		79	7 = Parameter card number
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
12	Station Pass Prediction Parameter Card 1 (Prediction-by-station option only)		
		1	Blank = Variable Δt integration
			1 = Fixed Δt integration
		2-11	Delta t (min.)
		12	0 = Do not compute bulge perturbation
			1 = Compute bulge perturbation
		13	0 = Do not compute drag perturbation
			1 = Compute drag perturbation
		14	0 = Do not compute radiation pressure perturbation
			1 = Compute radiation pressure perturbation
		15-16	Print option - sum the desired options:
			1 = Print t, $\underline{r}$, $\dot{\underline{r}}$
			2 = Print t, a, e, i, Ω, ω, U
			4 = Print t, ϕ, λ_E, h
			8 = Print t, ρ, $\dot{\rho}$, A, h
		17	0 = No binary tape output
			1 = Binary tape output
		18	0 = Do not compute prediction reliability
			1 = Compute prediction reliability (must have weighted 6 ot 7 element DC including the drag term)
		19-22	Blank = Station Pass Prediction Parameter Card 2 provides sensor input
			XXXXX = S-file tape provides sensor input
		23-32	Number of passes
		33-42	Delta t (min.), either side of closest approach

Deck Position	Card Type	Column Number	Punch
		43-52	Delta t (min.), output per delta t (must have weighted 6 or 7 element DC including the drag term)
		53-62	Minimum height (deg.)
		79	8 = Parameter card number
		80	P = Card type
13	Station Pass Prediction Parameter Card 2 (Prediction-by-station option only)		
		1-4	Station number
		5-14	ϕ_N° (station latitude)
		15-24	λ_W° (station longitude west)
		25-34	H (meters) (station height)
		79	9 = Parameter card number
		80	P = Card type
14	Program Execution Parameter Card		
		1	0, Blank = No differential correction 1 = Run differential correction
		2	0, Blank = No prediction 1 = Compute time prediction 2 = Compute station prediction
		3	0 = Print t, U, β for 1st pass 1 = Print t, U, β, Δe, $\Delta\alpha \cos \delta$, $\Delta\dot{e}$, $\Delta\alpha \cos h$ (km.), $\Delta\delta$ (km.) for 1st pass 2 = Print Δt, U, β, Δe, $\Delta\alpha \cos \delta$, $\Delta\dot{e}$, $\Delta\alpha \cos h$ (deg.), $\Delta\delta$ (deg.) for all passes 3 = Print Δt, U, β, $\Delta e.\hat{U}$, $\Delta e.\hat{V}$, $\Delta e.\hat{W}$, Δe, $\Delta\alpha \cos \delta$ $\Delta\dot{e}$, $\Delta\alpha \cos h$ (deg.), $\Delta\delta$ (deg.) and means for all above values for 1st pass only
		78-79	10 = Parameter card number
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
15	Observation Cards (optional)		
16	Sensor Cards (optional)		
17	Satellite Number Cards (optional)		
18	Element Set Cards (optional)		
19	End of Case Card		
20	End of Job Card		
21	End of Schedule Tape Card		
22	Blank Card		

4.3.10.3 OBSWGT Weighting Tape Format

Deck Position	Card Type	Column Number	Punch
1	Program ID Card		
		1-8	70WEIGHT
		9	11, 8, 2 punch = Card type
2	Observation/Sensor Weighting Card (in lieu of Function Weighting cards)		
		1-3	Sensor number
		4	0 = Sigma data is for all observations from the specified sensor 2 = Sigma data is for the next observation only
		9-16	$\sigma_1 = \rho$ (km.)
		17-24	$\sigma_2 = \dot{\rho}$ (km./sec.)
		25-32	$\sigma_3 = A^o$ or α^o
		33-40	$\sigma_4 = h^o$ or δ
		41	11, 8, 2 punch = Card type
NOTE:	If a sigma value is not input, leave the field blank.		
3	Function weighting card 1 (im lieu of Observation/Sensor Weighting card)		
		1-3	Sensor number
		4	1 = Parameter data is for a function
		5	0, Blank = Last parameter is contained on this card 1 = Next card is also a parameter card

Deck Position	Card Type	Column Number	Punch
		9-16	Function ID (left adjusted)
		17-80	Parameter (follow the last parameter by an 11, 8, 2 punch)
4	Function Weighting Cards 2-10 (in lieu of Observation/Sensor Weighting card)		
		1-3	Sensor number
		4	1 = Parameter data is for a function
		9-16	Function ID
		17-24	9th parameter (if appropriate)
		25-32	10th parameter, followed by an 11, 8, 2 punch

4.3.10.4 Output

The maximum program printout consists of differential correction output, prediction output, prediction reliability output, and error comments.

4.3.10.4.1 Differential Correction Output

The differential correction output may appear in several different forms depending on the input option selection. Basically, two formats are available and the other options add or subtract information from them.

4.3.10.4.1.1 Type 1

The first type of printout consists of the residuals for all of the observations, followed by the RMS and corrections to the elements, and the corrected elements. The format of the output is like that of SGPDC (see section 4.3.8.3)

4.3.10.4.1.2 Type 2

The second type of differential correction output contains the following information:

1. Station number
2. Time of observation
3. Residuals for U, V and W in kilometers where U is the unit vector along radius vector, V is the transverse unit vector, and W is the unit vector perpendicular to the orbit plane.
4. Range, range rate, and angular residual means and standard deviations.
5. U, V and W residual means and standard deviations.

SAMPLE PRINTOUT, SPWDC

DIFFERENTIAL CORRECTION

PART 1

SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION PRG MARCH 30, 1964 PAGE 2

SATELLITE NO. 502 SATELLITE NAME: 62 B-TAU 1 ELEMENT SET NO. 902 TIME OF EPOCH 86.9880254 YEAR 1964

STA NO.	Y	MM	DD	HH	MM	SS.SS	R J	RANGE RES. KM.	RT ASCEN RES. KM.	DECL. RES. KM.	AZIMUTH RES. KM.	ELEV. RES. KM.	RR. RES. KM./SEC.	VECTOR MAG. KM.	DELTA T MIN.	DEG.	BETA DEG.
336	4	03	26	23	42	45.40		-.1400+1			-.1980+1	.1811+1	.5095-2	.302+1	-.0051	31	.011
336	4	03	26	23	42	55.30		-.450218			-.1995+1	.2232+1	.4740-2	.302+1	-.0048	32	.007
336	4	03	26	23	43	5.36		-.1958+1			-.647705	.1463+1	.5408-2	.251+1	-.0023	32	.008
336	4	03	26	23	43	15.35		-.1791+1			-.1[illegible]7+1	.702853	.8378-2	.255+1	-.0041	33	[illegible]
336	4	03	26	23	43	25.34		-.1273+1			-.289403	.435465	.6347-2	.137+1	-.0009	34	.010
336	4	03	26	23	43	35.31		-.2142+1			-.1659+1	-.3904+1	.4445-2	.239+1	-.0024	34	.014
336	4	03	26	23	44	5.26		-.172984			-.1517+1	-.8541+1	.5827-2	.152+1	-.0032	36	.0[illegible]
336	4	03	26	23	44	15.25		-.658802			-.2421+1	.1374+1	.7188-2	.281+1	-.0051	37	.010
336	4	03	26	23	44	25.22		-.1023+1			-.2057+1	.1944+1	.8283-2	.294+1	-.0041	38	.015
336	4	03	26	23	44	35.21		-.879983			-.1427+1	.1158+1	.7043-2	.225+1	-.0027	38	.01[illegible]
336	4	03	26	23	44	45.18		-.702288			-.2549+1	.2143+1	.7861-2	.340+1	-.0050	39	.015
336	4	03	26	23	44	55.17		-.1841+1			-.1414+1	.2461+1	.6959-2	.353+1	-.0020	39	.024
336	4	03	26	23	45	5.16		-.1282+1			-.1809+1	.2768+1	.7068-2	.354+1	-.0028	40	.022
336	4	03	26	23	45	15.13		-.115763			-.1703+1	.2034+1	.7867-2	.245+1	-.0030	41	.0[illegible]
336	4	03	26	23	45	25.12		-.1121+1			-.1702+1	.820042	.8036-2	.21[illegible]	-.0028	41	.014

PART 2

SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION PRG MARCH 30, 1964 PAGE 10

SATELLITE NO. 502 SATELLITE NAME: 62 B-TAU 1 ELEMENT SET NO. 902 TIME OF EPOCH 86.9880254 YEAR 1964

RMS KM.	RMS2 KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA UO RADIANS	DELTA NODE RADIANS	DELTA I RADIANS	DELTA A/M M**2/KGS
.228562+1	.573778-2	-.14171770-7	-.10734-3	.14809-3	.35796-3	-.11472-4	-.50989-5	

CORRECTED ELEMENTS

DEGREES	TO DAYS IN YR	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	MASS KGS.	PER ALT ST. MI.	PA MINUTES
132.75368	86.98802	1.1997489	.13471	70.342	113.166	335.533	.60980	153.1	111.071

SAMPLE PRINTOUT, SPWDC

PART 3

SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION PRG MARCH 30, 1964 PAGE 19

SATELLITE NO. 502 SATELLITE NAME: 62 B-TAU 1 ELEMENT SET NO. 902 TIME OF EPOCH 86.9880254 YEAR 1964

DC CONVERGED - THE NEXT CORRECTIONS WOULD BE ...

OLD RMS KM.	NEW RMS KM.	OLD RMS2 KM/SEC	NEW RMS2 KM/SEC	DELTA N/N	DELTA AXN	DELTA AYN	DELTA UO RADIANS	DELTA NODE RADIANS	DELTA I RADIANS	DELTA A/M M**2/KGS
.186+2	.229+1	.00000	.600-2	.24337933-6	-.34719-4	.44799-4	.13196+3	.35484-4	.34774-4	

NO. OF RESIDUALS USED = 322 NO. OF RESIDUALS REJECTED = 24

DEGREES	TO DAYS IN YR	A EARTH RADII	E	I DEG.	NODE DEG.	OMEGA DEG.	MASS KGS.	PER A T ST. MI.	PA MINUTES
OLD ELEMENTS WITH RESPECT TO OLD EPOCH									
269.13954	87.55715	1.1998191	.13533	70.346	112.121	334.544	.60960	150.5	111.081
OLD ELEMENTS WITH RESPECT TO INTERMEDIATE EPOCH									
132.58292	86.98802	1.1997776	.13522	70.346	113.177	335.360	.60960	150.8	111.075
NEW ELEMENTS WITH RESPECT TO INTERMEDIATE EPOCH									
132.75368	86.98802	1.1997489	.13471	70.342	113.166	335.533	.60960	153.1	111.071
NEW ELEMENTS WITH RESPECT TO NEW EPOCH									
232.07540	88.39754	1.1990382	.13547	70.334	110.559	333.742	.60960	147.3	110.973

ELEMENT SET UPDATED

```
SAMPLE PRINTOUT, SPWDC
DIFFERENTIAL CORRECTION, ALTERNATE FORMAT
      PART 1
SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION PRG       MARCH 31, 1964                          PAGE   4

SATELLITE NO. 502  SATELLITE NAME: 62 B-TAU 1  ELEMENT SET NO. 902               TIME OF EPOCH    86.9880254  YEAR 1964

   STA         TIME            R             DELTA     DELTA     DELTA
   NO. Y MM DD HH MM 55.SS     J             U, KM.    V, KM.    W, KM.

   336 4 03 26 23 42 45.40     *             .1044*1   .2435*1   .1462*1
   336 4 03 26 23 42 55.39     *             .1821*1   .2254*1   .875030
   336 4 03 26 23 43  5.36     *             .485701   .1098*1   .2207*1
   336 4 03 26 23 43 15.35     *            -.148830   .1965*1   .1620*1
   336 4 03 26 23 43 25.34     *            -.166465   .461576   .1286*1
   336 4 03 26 23 43 35.31     *            -.981758   .1239*1   .1792*1
   336 4 03 26 23 44  5.26     *            -.198823   .1516*1   .116173
   336 4 03 26 23 44 15.25     *             .830540   .2383*1   .1246*1
   336 4 03 26 23 44 25.22     *             .1166*1   .1939*1   .1869*1
   336 4 03 26 23 44 35.21     *             .1106*1   .1290*1   .1478*1
   336 4 03 26 23 44 45.18     *             .1555*1   .2317*1   .1939*1
   336 4 03 26 23 44 55.17     *             .1488*1   .928329   .3064*1
   336 4 03 26 23 45  5.16     *             .1834*1   .1303*1   .2736*1
   336 4 03 26 23 45 15.13     *             .1736*1   .1423*1   .1422*1
   336 4 03 26 23 45 25.12     3             .186095   .1290*1   .1769*1
     PART 2
SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION PRG       MARCH 31, 1964                          PAGE   6

SATELLITE NO. 502  SATELLITE NAME: 62 B-TAU 1  ELEMENT SET NO. 902               TIME OF EPOCH    86.9880254  YEAR 1964


      82  OBSERVATIONS FOR STATION 336


  RANGE     RT ASCEN   DECL.     AZIMUTH    ELEV.      RR. RES.    VE
 RES. KM.   RES. DEG.  RES. DEG. RES. DEG.  RES. DEG.  KM./SEC.    MAG
 .1763*1                         .103887    .1894*1    .2772-1       MEANS

 .1.19*2                         .435875    .219095    .3692-1      STANDARD DEVIATIONS


            DELTA      DELTA      DELTA
            U, KM.     V, KM.     W, KM.

            .1061*1    .1559*2    .370493       MEANS

            .2697*1    .1605*2    .2160*1       STANDARD DEVIATIONS
```

4.3.10.4.2 Prediction Output

For prediction by time there are three output options which may be requested separately or in combination. These contain in addition to time:

1. First option
   a. Position (X RADII, Y RADII, Z RADII)
   b. Velocity (XDOT RAD/KEMIN, YDOT RAD/KEMIN, ZDOT RAD/KEMIN)
2. Second option
   a. Osculating orbital elements
      a (ARADII)
      e (E)
      i (I DEG)
      Ω (NODE DEG)
      ω (OMEGA DEG)
      U (U DEG)
3. Third option
   a. Subsatellite track
      ϕ (PHI DEG)
      λ_E (LAMBDA DEG)
      h (H KM)

For prediction by station pass there is an additional option to output:

1. Time
2. Acquisition coordinates - ρ, $\dot{\rho}$, A, h

4.3.10.4.3 Prediction Reliability Output (not currently used)

The optional prediction reliability output will print at each prediction point:

1. Standard deviation in predicted position.
2. Standard deviation in predicted velocity components.

These values will be given referred to the cross-track, in-track, and out-of-plane coordinates and also referred to the inertial x, y, z coordinate system.

4.3.10.4.4 Error Comments

All error printouts by the program are self-explanatory and need not be listed.

SAMPLE PRINTOUT, SPWDC
TIME PREDICTION, 3 OPTIONS

```
SPECIAL PERTURBATIONS WITH WEIGHTED DIFFERENTIAL CORRECTION PRG        MARCH 30, 1964                                    PAGE  20

SATELLITE NO. 502  SATELLITE NAME: 62 B-TAU 1  ELEMENT SET NO. 903            TIME OF EPOCH   88.3975473  YEAR 1964

TIME (DAYS SINCE BEGINNING OF YEAR)
                          X     RADII           Y     RADII          Z     RADII         XDOT RAD/KEMIN   YDOT RAD/KEMIN   ZDOT RAD/KEMIN
                          A     RADII           E                    I     DEG           NODE     DEG     OMEGA     DEG    W        DEG
                          PHI   DEG             LAMBDA DEG           H     KM
       88.2924305
                          -.347368322254    .988468767350    -.685749711-1    -.366359402483    -.114960A229-1    .970980973681
                           .120077974 3+1   .135578883520     .703493194 3+2   .110759A952+3     .33393440 22+3   -.9315963447+1
                          -.3780058231+1    .1784121185+3     .3008008788+3
```

4.3.11 ORBITAL INTERSECTION - XROADS

4.3.11.1 Purpose

The XROADS program computes the point of closest proximity between two orbits, and operates in one of four modes:

a. "Primary" Mode - the program establishes a position and time of intersection or closest approach of two orbits.

b. "Test Case" Mode - the program computes the elements of a second orbit, given an initial orbit and the intersection parameters.

c. "Direct Entrance to Function Minimization" Mode - when the time of intersection is known quite accurately, the program goes directly to the final stages of proximity computation.

d. "Ephemeris Computation Only" Mode - the program computes ephemerides in position and velocity for given element sets.

4.3.11.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-14	XRØADS
		17	0 = Parameter cards and Element Set cards input
			1 = Parameter cards, Satellite Number cards and E-file tape inputs.
		18	0 = Hardcopy output
		80	J = Card type
5	Parameter Card Number 1		
		7	1 = Parameter card number

Deck Position	Card type	Column Number	Punch
5 (Continued)		8	0 = Primary mode case 1 = Test mode case 2 = Direct mode case 3 = Ephemeris mode case
		9-12	Year of estimated intersection (if zero, program computes value)
		13-19	DDD.DDD = Days since beginning of year of estimated intersection.
		20-27	+.xxx±xx (Radians) = Convergence criterion 1 (typically = + .100-04)
		28-35	+.xxx±xx (Dimensionless) = Convergence criterion 2 (typically = + .200-01)
		36-43	+.xxx±xx (Radians) = Convergence criterion 3 (typically = + .100-04)
		44-51	+.xxx±xx (Days) = Convergence criterion 4 (typically = +.100-07)
		52-59	+.xxx±xx (Dimensionless) = Convergence criterion 5 (typically = +.200+02)
		60-67	+.xxx±xx = Weighting factor (typically = +.100+-1)
		68-69	Maximum number of iterations in Loop 1 - e.g., 10
		70-71	Maximum number of iterations in Loop 2 - e.g., 10
		72-73	Maximum number of iterations in Loop 3 - e.g., 10
		74-75	Maximum number of iterations in Loop 4 - e.g., 20
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
6	Parameter Card Number 2		
		7	2 = Parameter card number
		8-15	+.xxx±xx $(km)^2$ = Variance in x
		16-23	+.xxx±xx $(km)^2$ = Variance in y
		24-31	+.xxx±xx $(km)^2$ = Variance in z
		32-39	+.xxx±xx $(sec)^2$ = Variance in t
		40-47	+.xxx±xx (days) = Interval for emphemeris output
		48-49	Half the number of time points for ephemeris output
		80	P = Card type
7	Parameter Card Number 3 (Required only for Test Case Mode - Case 1)		
		7	8 = Card number
		8-14	DDD.DDD (Days since beginning of year) = Epoch for which the second element set is to be generated by the test case generator (case 1)
		15-21	DDD.DDD (Days since beginning of year) = Time at which input perturbations are applied by the test case generator
		22-29	±.xxx±xx (m/sec) = Tangential component of velocity impulse
		30-37	±.xxx±xx (m/sec) = Normal component of velocity impulse
		38-45	±.xxx±xx (m/sec) = Transverse component of velocity impulse
		46-53	±.xxx±xx (m) = x component of position error
		54-61	±.xxx±xx (m) = y component of position error
		62-69	±.xxx±xx (m) = z component of position error
		70-77	±.xxx±xx (Sec) = Time error
		80	P = Card type

Deck Position	Card Type	Column Number	Punch
8	Data Cards		

a. Case 0, Case 2 and Case 3:

(1) Input Option 0:

(a) Parameter card 1

(b) Parameter card 2

(c) Element set 1

(d) Element set 2

(2) Input Option 1:

(a) Parameter card 1

(b) Parameter card 2

b. Case 1

(1) Input Option 0:

(a) Parameter card 1

(b) Parameter card 2

(c) Parameter card 3

(d) Element set 1

9	End of Case Card		
10	End of Job Card		
11	End of Schedule Tape Card		
12	Blank Card		

4.3.11.3 Output

4.3.11.3.1 Normal Output

The primary output of the program consists of the position and time in each of the orbits at the intersection as well as the differential quantities which describe the characteristics of the intersection. The specific values are:

1. Times in days (T1, T2)
2. Position coordinates in kilometers (X1, Y1, Z1, X2, Y2, Z2)
3. Velocity components in km/sec (X1D, Y1D, Z1D, X2D, Y2D, Z2D)
4. Velocity magnitudes (S1D, S2D)

5. Geodetic latitude at the intersection point with geodetic radius (GEOD. LAT)
6. Longitude (LONG)
7. Slant height (HEIGHT)
8. Time difference in seconds (DT)
9. Position coordinate differences in meters (DX, DY, DZ)
10. Velocity component differences in meters per second (DXD, DYD, DZD)
11. Velocity magnitude difference in meters per second (DSD)
12. Component of velocity along radius vector in meters/sec (DRD)
13. Component of velocity impulse tangent to vehicle path in meters/sec (TANGENTIAL COMP. OF DELTA RDOT)
14. Component of velocity impulse which is normal to vehicle path but in the orbital plane in meters/sec (NORMAL COMPONENT OF DELTA RDOT)
15. Component of velocity impulse which is normal to the orbital plane in meters/sec (TRANSVERSE COMP. OF DELTA RDOT)
16. F, E^2 - DG, A, D + G, B where

$$F = \frac{(x_2 - x_1)^2}{\sigma_x^2} + \frac{(y_2 - y_1)^2}{\sigma_y^2} + \frac{(z_2 - z_1)^2}{\sigma_z^2} + \frac{(t_2 - t_1)^2}{\sigma_t^2}$$

$$A = \frac{\partial F}{\partial t_1}$$

$$B = \frac{\partial F}{\partial t_2}$$

$$D = \frac{\partial^2 F}{\partial t_1^2}$$

$$E = \frac{\partial^2 F}{\partial t_1 {}^2 t_2}$$

$$G = \frac{\partial^2 F}{\partial t_2^2}$$

4.3.11.3.2 Ephemerides

The optional ephemerides output consists of the position and velocity in each of the orbits for a number of times equally spaced about the mean time of the

intersection. The quantities are:

1. Position coordinates in kilometers (X1, Y1, Z1, X2, Y2, Z2)
2. Times in days (T1, T2)
3. Velocity componenets in km/sec (X1D, Y1D, Z1D, X2D, Y2D, Z2D)
4. True arguments of latitude in degrees (U1, U2)
5. Separation in kilometers (SEPARATION

4.3.11.3.3 Error Comments

Six significant error printouts may also appear from the program:

1. N1 MAX EXHAUSTED - failure to converge on t_u (times at which u's are equal).
2. N2 MAX EXHAUSTED - function F is greater than allowed value (see input parameters) at converged value of t_u.
3. N3 MAX EXHAUSTED - failure to converge on the times corresponding to the geometrically determined values of u.
4. N4 MAX EXHAUSTED - failure to converge in the function minimization loop.
5. SADDLE POINT - function minimization process yields times at a saddle point.
6. RELATIVE MAXIMUM - function minimization process yields times at a relative maximum.

In all six cases, the program continues processing, in the first four cases using the latest values of t.

SAMPLE PRINTOUT, XROADS

EPHEMERIS

T1	330.04476	DAYS	X1	5407.0655	KM	Y1	[illegible].2073	KM	Z1	2066.1035	KM
			X1D	-3.64742	KM/SEC	Y1D	5.6[illegible]3	KM/SEC	Z1D	2.83967	KM/SEC
T2	330.04476	DAYS	X2	2160.2690	KM	Y2	-4[illegible].3937	KM	Z2	5454.2263	KM
			X2D	-4.07245	KM/SEC	Y2D	4.[illegible]3	KM/SEC	Z2D	4.76443	KM/SEC
U1	35.642	DEG	U2	50.453	DEG		SEPARATION	9164.411	KM		
T1	330.04490	DAYS	X1	5362.7491	KM	Y1	3[illegible].4746	KM	Z1	2110.[illegible]84	KM
			X1D	-3.72024	KM/SEC	Y1D	5.5[illegible]0	KM/SEC	Z1D	2.[illegible]0889	KM/SEC
T2	330.04490	DAYS	X2	2111.2596	KM	Y2	-4[illegible].0301	KM	Z2	5910.9991	KM
			X2D	-4.10033	KM/SEC	Y2D	4.0[illegible]6	KM/SEC	Z2D	4.69687	KM/SEC
U1	36.312	DEG	U2	51.165	DEG		SEPARATION	9190.334	KM		
T1	330.04504	DAYS	X1	6317.5402	KM	Y1	3[illegible].3823	KM	Z1	2133.7426	KM
			X1D	-3.79251	KM/SEC	Y1D	5.5[illegible]3	KM/SEC	Z1D	2.79474	KM/SEC
T2	330.04504	DAYS	X2	2061.9107	KM	Y2	-4[illegible].0332	KM	Z2	5944.9095	KM
			X2D	-4.12756	KM/SEC	Y2D	4.1[illegible]2	KM/SEC	Z2D	4.52465	KM/SEC
U1	36.981	DEG	U2	51.882	DEG		SEPARATION	9214.942	KM		

SAMPLE PRINTOUT, XROADS

NORMAL PORTION

SADDLE POINT

T1	330.04643	DAYS	X1	5820.5675	KM	Y1	4[illegible].7226	KM	Z1	2492.8924	KM
			X1D	-4.48110	KM/SEC	Y1D	5.1[illegible]5	KM/SEC	Z1D	2.52434	KM/SEC
S1D	7.25738	KM/SEC	GEOD. LAT	19.188	DEG	LONG	313.[illegible]19	DEG	HEIGHT	1132.0511	KM
T2	330.04866	DAYS	X2	686.2333	KM	Y2	-2[illegible].2033	KM	Z2	6694.6094	KM
			X2D	-4.59584	KM/SEC	Y2D	5.2[illegible]5	KM/SEC	Z2D	2.54[illegible]82	KM/SEC
S2D	7.40463	KM/SEC	GEOD. LAT	68.748	DEG	LONG	20[illegible].44[illegible]	DEG	HEIGHT	829.8464	KM
DT	192.760	SEC	DX	-5132334.191	M	DY	-[illegible]58702[illegible].975	M	DZ	241716.932	M
			DXD	-114.748	M/SEC	DYD	1[illegible]0[illegible]8	M/SEC	DZD	16.484	M/SEC
DSD	147.265	M/SEC	DRD	153.103	M/SEC	F	26469096 [illegible]0				

TRANSVERSE COMP. OF DELTA ROOT	-27.754	M/SEC	ESQ -DG	.[illegible]6060941+23	DAY^{-4}	A	-.9639831541+1
TANGENTIAL COMP. OF DELTA ROOT	147.144	M/SEC	D + G	.-8114063+11	DAY^{-2}	B	-.7517799855-2
NORMAL COMPONENT OF DELTA ROOT	31.920	M/SEC					

4.3.12 OTHER

The following programs in the Element Determination area are seldom used by the analyst. A brief description of each program is given.

4.3.12.1 CCOE

The CCOE program calculates, from an input element set, the cartesian coordinates (x, y, z) and the components of velocity, $(\dot{x}, \dot{y}, \dot{z})$ of a satellite for a specified length of time at given intervals. The output can be expressed in either kilometers or earth radii.

4.3.12.2 HANSEL

The HANSEL program produces a teletype tape for transmission to SCAF (Space Track Center Alternate Facility). The tape contains the SPADATS object numbers and element set numbers of all satellites whose elements were updated during a specified time period (normally 24 hours.)

4.3.12.3 MSGV

The MSGV program produces, for transmission to specified field sites, a set of teletype tapes containing newly updated element sets. The type of element sets (seven or four cards) can be specified as an input option. The program is normally run once a day.

4.3.12.4 SEAI

The SEAI program generates a new SEAIC tape from standard SPADATS data cards. The program will build a new tape or update an existing tape by replacing, adding or deleting records.

The files contained on the SEAIC tape are as follows:

1. Sensor file
2. Element file
3. Acquisition file
4. Information file
5. Communication file

4.3.12.5 SUM

The SUM program summarizes the contents of the SEAIC tape. All files or only selected files (toggle option) can be specified for output in hard copy format.

4.4 OBSERVATION ACQUISITION AREA

The Observation Acquisition area includes the programs that generate acquisition coordinates (GLASGP, IAP, BNSCHED, OBSERV, XYZLA, ORPS and POSE), the position and status programs (PSR, PREPINT, and GRNTRK) and the bulletin programs (BLTNSGP and SYSBULL).

4.4.1 BAKER-NUNN SCHEDULE - BNSCHED

4.4.1.1 Purpose

The BNSCHED program computes sets of predicted acquisition coordinates for a group of satellites and specified Baker-Nunn sensors.

4.4.1.2 Input - Schedule Tape Mode Only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-15	BNSCHED
		17	0 = Parameter card, Sensor Number card, S-file, E-file (all element sets) and I-file tape inputs
			1 = Parameter card, Sensor Number card, Element Set cards, S-file and I-file tape inputs
			2 = Parameter card, Sensor Number card, Satellite Number card, S-file, E-file and I-file tape inputs
			3 = Parameter card, Sensor Number card, Sensor card, E-file (all element sets) and I-file tape inputs
			4 = Parameter card, Sensor Number card, Sensor card, Element Set cards and I-file tape inputs
			5 = Parameter card, Sensor Number card, Satellite Number card, Sensor card, E-file and I-file tape inputs
		18	0 = Hardcopy and TTY output
			1 = Hardcopy output

Deck Position	Card Type	Column Number	Punch
5	Base Time Card (optional)		
		1	Base Year (last digit)
		2-10	Base Day
		25-28	Base message number
		79	3 = Card type
		80	P = Card type

NOTE: The Base Time card is optional. If not used, the information is taken from the last case executed.

Deck Position	Card Type	Column Number	Punch
6	Parameter Card		
		2-10	Beginning time (days since Base Day)
		11-19	Ending time (days since Base Day)
		20-21	Total number of sensors on the Sensor Number card(s)
		29-33	Minimum start track angle (deg.)
		34-38	Minimum elevation angle (deg.)
		80	P = Card type
7	Sensor Number Card		
		1-3	Sensor number
		4	1 = Secret
			2 = Secret/NoForn
			3 = Confidential
			4 = Confidential/NoForn
			5 = Unclassified
			6 = Unclassified/EFTO
		5	Y = Emergency
			Ø = Operations - Immediate
			P = Priority
			R = Routine

NOTE: Cols. 1-5 may be repeated, once for each sensor, up thru col. 75.

Deck Position	Card Type	Column Number	Punch
		80	P = Card type
8	Satellite Number Card		
		1-8	Satellite number (rt.-adj.)

Deck Position	Card Type	Column Number	Punch
9	Data Cards:		
	(1) Element Set cards (optional)		
	(2) Sensor cards (optional)		
10	End of Case Card		
11	End of Job Card		
12	End of Schedule Tape Card		
13	Blank Card		

4.4.1.3 Output

Program printout consists of the following information:

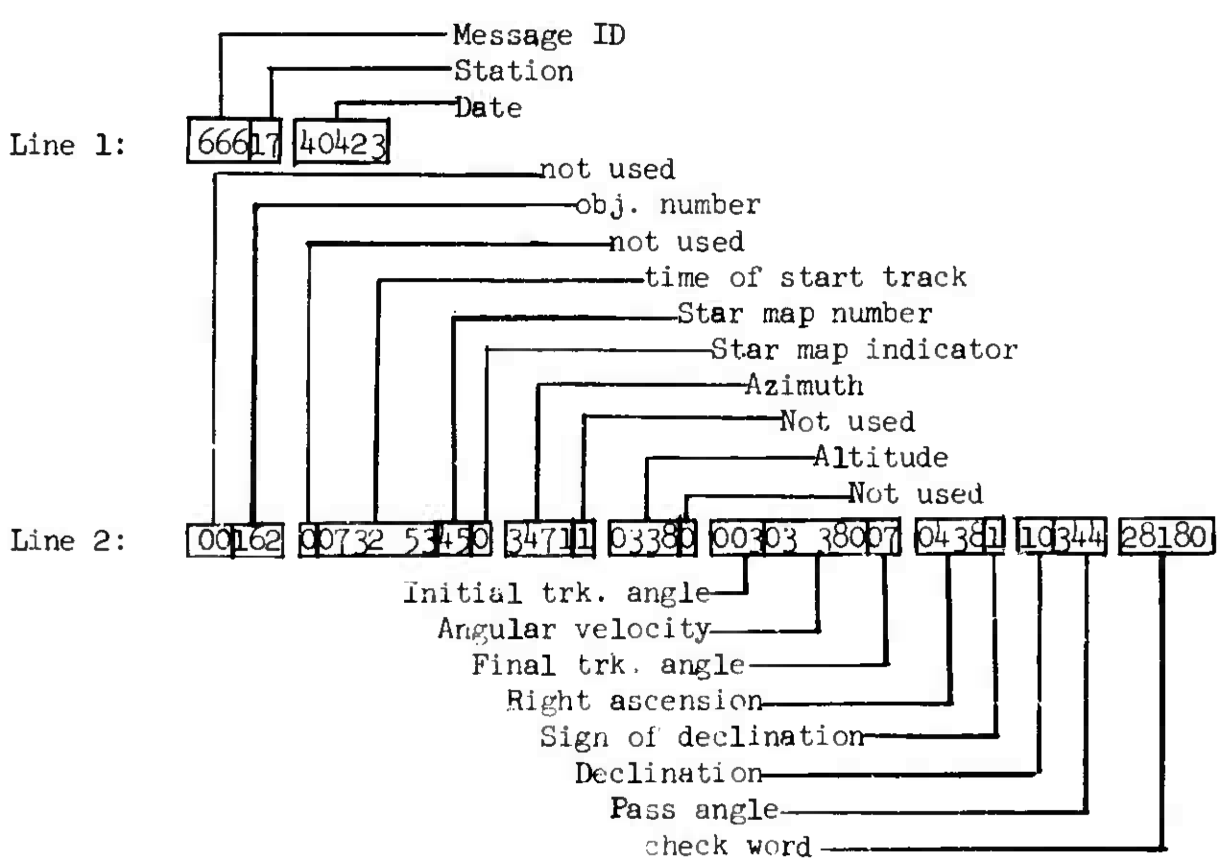
1. Addressing information
2. Message identifier
3. Station number
4. Date -- day, month, year
5. Acquisition data containing:
   a. object number
   b. time of start track -- hours, minutes, seconds
   c. star chart map number and indicator
   d. azimuth in tenths of degrees
   e. altitude in tenths of degrees
   f. initial track angle in degrees
   g. angular velocity in seconds per second
   h. final track angle in degrees
   i. right ascension in hours and minutes
   j. sign of declination and declination in degrees
   k. position angle in degrees
   l. check word
   m. time of start of next predictions

SAMPLE PRINTOUT, BNSCHED

```
VD   DXA325DHB744
OO ENTAFB JHNISL
DE SPA TRK 41H 2Ø/1732Z
ANR
O 201732Z ZEX
FM SCAF LG HANSCOM FLD MASS
TO JHNISL/DET 4 2SURVILLSQ JOHNSTON ISLAND
IFO ENT AFB/1ST AERO ENT AFB COLO
BT
UNCLASS/E F T O / 1AERO OOPS 66617 4Ø423 Ø732
CAMERA PREDICTIONS FOR STATION AT SAND ISLAND(B/N)

66617 40423
ØØ162 ØØ732 5345Ø 34711 Ø338Ø ØØ3Ø3 38ØØ7 Ø4381 1Ø344 2818Ø
ØØ162 ØØ734 1934Ø 34541 Ø287Ø Ø13Ø4 37Ø18 Ø4491 Ø2349 79599
ØØ162 ØØ735 46Ø3Ø 34131 Ø244Ø Ø28Ø5 73Ø35 Ø458Ø 1Ø353 51951
ØØ162 ØØ737 1215Ø 33381 Ø211Ø Ø49Ø7 28Ø58 Ø4Ø4Ø 24357 88582
ØØ162 ØØ738 3826Ø 32311 Ø196Ø Ø78Ø8 22Ø88 Ø5Ø9Ø 43ØØ1 28Ø98;
ØØ162 ØØ74Ø Ø535Ø 31161 Ø2Ø1Ø 1Ø8Ø7 79118 Ø5Ø5Ø 62ØØ6 74184
ØØ162 ØØ741 3135Ø 3Ø241 ØØ26Ø 135Ø6 37142 Ø414Ø 8ØØ23 87255
ØØ162 ØØ742 584ØØ 29681 Ø264Ø 154Ø4 8916Ø 2Ø27Ø 83144 66293
ØØ162 ØØ744 2438Ø 29411 Ø3Ø9Ø 168Ø3 76172 19ØØØ 73171 ØØ523
 NEXT PREDICTIONS START AT DAY 115.499.
```

EXPLANATIONS:



4.4.2 BULLETIN WITH SIMPLIFIED GENERAL PERTURBATIONS - BLTNSGP

4.4.2.1 Purpose

The BLTNSGP program computes an ephemeris (set of predictions) of future satellite positions based on the orbital elements describing the motion of the satellite. The program integrates the orbit using the SGP technique.

4.4.2.2 Input

4.4.2.2.1 Automatic Mode - in an OCS sequence

a. The satellite number from the SATTB tape.

b. The corresponding element set from the E-file tape, including the number of the initial revolution of Part II.

c. OCS Toggle number On = Desired OCS sequence.

d. Toggle 44 On = Non-addressed bulletin on tape 5 for printing/punching.

4.4.2.2.2 Schedule Tape Mode - (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape		
2	Job		
3	Remard (optional)		
4	Program ID		
		1-6	SPSJØB
		9-15	BLTNSGP
		17	0 = Satellite numbers card, E-file and I-file tape inputs
			1 = Parameter card and element set cards inputs
		18	0 = Hardcopy and TTY outputs
			1 = Hardcopy output comments (alpha number)
		19-72	Comments (alphanumeric)

Deck Position	Card Type	Column Number	Punch
5	Satellite Numbers Card (optional)		
6	Parameter Card (optional)		
		1	N = Non-addressed bulletin
			- = Pre-addressed bulletin from I-file
		2-24	Satellite Number
		7	0 = TTY input
			1 = No TTY input
		8-9	Last two digits of year satellite was launched
		10-11	01 = α } IGY World Wide Code
			02 = β
			03 = γ
			04 = δ
		12	Component (No. assoc. pcs.)
		13-27	Radio frequencies, 5 digits each, in 100ths of a megacycle
		34-40	Initial revolution
		41-47	Final revolution
		48	0 = No grid
			1 = Standard grid
			2 = Special grid
		49-55	Grid revolution
		60-61	Grid increment (no decimal pt.)
		62-65	Grid latitude
		66-67	Bulletin year
		68-70	Bulletin number
		80	P = parameter card
7	Data Cards:		

a. Input option 0: None

b. Input option 1:

(1) 7-card Element Set Cards

PART III. REDUCTION TO OTHER LATITUDES AND HEIGHTS FOR REV

LAT N	MINUTES PLUS	LONG CORR	HEIGHT KILOM	LAT S	MINUTES PLUS	LONG CORR	HEIGHT* KILOM*
SN 00	.00	.00	1117.8V	NS 00	53.20	193.39	1222.8V*
SN 10	2.97	359.24	1096.7V	NS 10	56.28	192.66	1246.1V*
SN 20	5.95	358.39	1079.0V	NS 20	59.39	191.85	1268.3V*
SN 30	8.92	357.32	1065.2V	NS 30	62.53	190.82	1288.7V*
SN 40	11.85	344.82	1055.4V	NS 40	65.69	189.39	1306.3V*
SN 50	14.87	353.54	1049.6V	NS 50	68.89	187.18	1320.2V*
SN 60	17.90	349.60	1047.8V	NS 60	72.15	183.34	1329.6V*
SN 70	21.02	341.25	1049.7V	NS 70	75.52	175.17	1333.5V*
SN 80	24.79	309.12	1056.9V	NS 80	79.57	143.76	1329.7V*
N PT	26.36	277.25	1061.3V	S PT	81.26	112.30	1325.5V*
NS 80	27.93	245.03	1066.4V	SN 80	82.94	79.77	1319.6V*
NS 70	31.71	212.23	1081.7V	SN 70	86.97	46.35	1299.6V*
NS 60	34.88	203.76	1097.2	SN 60	90.31	37.80	1277.4V*
NS 50	37.95	199.76	1114.6	SN 50	93.51	33.82	1252.2 *
NS 40	40.99	197.50	1133.7	SN 40	96.65	31.53	1225.0 *
NS 30	44.03	196.02	1154.4	SN 30	99.74	30.05	1196.9 *
NS 20	47.07	194.96	1176.4V	SN 20	102.80	28.99	1169.1V*
NS 10	50.13	194.12	1199.4V	SN 10	105.82	28.14	1142.6V*
NS 00	53.20	193.39	1222.8V	SN 00	108.94	27.37	1117.4V*

4.4.2.3.4 Part IV - The description of SATOR (modified Orbital Elements for Prediction Purposes) is as follows:

Code word: SATOR

Symbolic form:

SATØR	aabbc	deeff	ggggZ	hhhhX	NØWES
iiiii	jkkkl	ARPER	lllll	mnnnX	PERIØD
ooooo	ppppp	ECCEN.	qqqqq	PERRA	rrrrrr
RAFRE	sssss	(sssss repeated as necessary)		RATASC	ttttt

Key:

aa = Last two digits of year satellite launched

bb = Greek letter designation, 01 - Alpha, 02 - Beta, etc.

c = Component

d = Reference time (time of perigee passage closest to epoch): last digit of numerical notation for month; i.e,, 1 = January or November, 2 = February or December, 3 = March, etc.

ee = Reference time: date

ff = Reference time: hour

gggg = Reference time: minutes and hundredths of minutes

Z = Universal time, Greenwich Mean Time

hhhh = Inclination in degrees and hundredths of degrees. If the orbit inclination is negative (satellite launched westward) group is preceded by NEGAT.

X = Always an X

PART IV

SATOR	6404A	20311	56582	8148X	NOWES
27906	20718	ARPER	08315	2186X	PERIOD
08894	00000	ECCEN	01882	PERRA	46036
RAFRE	36.70	00000	RADEG	03279	

4.4.3 GENERAL LOOK ANGLES USING SIMPLIFIED GENERAL PERTURBATIONS - GLASGP

4.4.3.1 Purpose

The GLASGP program computes sets of predicted acquisition coordinates for a group of satellites and their associated sensors, using the anomalistic data in an element set. The program integrates an orbit using the SGP technique.

4.4.3.2 Input

4.4.3.2.1 Automatic Mode - in an OCS sequence

a. The satellite numbers from the SATTB tape.

b. The corresponding element sets from the E-file tape.

c. The sensors associated with each satellite from the A-file tape.

d. The acquisition coordinates for each sensor from the A-file tape.

e. The Look Angle message parameters from the A-file tape.

f. OCS number Toggle On = Desired OCS sequence.

g. Toggle 44 On = addresses from I-file, not C-file

4.4.3.2.2 Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-14	GLASGP
		17	0 = Satellite number card, S-file, E-file and A-file tape inputs
			1 = Sensor, Element Set and Acquisition cards
		18	2 = Hardcopy and TTY outputs
			3 = Hardcopy output
		80	J = Card type

Deck Position	Card Type	Column Number	Punch
5	Data Cards:		

a. Input Option 0:

(1) Satellite Number card (max. = 4 per case)

b. Input Option 1:

(1) Sensor cards (max. = 31 per case)

(2) Element Set cards

(3) Acquisition cards (max. = 31 per case)

<u>NOTE</u>: Initial and final revolution are specified only if N_o and N_F +15 on the 7th Element card are not acceptable to the analyst.

6 End of Case Card

7 End of Job Card

8 End of Schedule Tape Card

9 Blank Card

4.4.3.3 <u>Output</u>

The program printout is essentially a Look Angle message containing the following information:

1. Addressing information
2. Satellite name and number
3. Element set number
4. Initial and final revolution of computation
5. Sets of acquisition coordinates containing:
   a. Time
   b. Angular quantities and/or
   c. Range and/or
   d. Range rate and if desired
   e. Elevation angle of the sun and satellite illumination.

SAMPLE PRINTOUT, GLASGP

```
DO SPATRK
DE RUWBALD 261A 17/1P2NZ
ZNR
0 1718202 ZEX
FM 1AEROSPCTLSC ENT AF8 COLO
TO SPATRK/1AERCSFCTLSQ ENT AFB COLO
AFGRNC
BT
UNCLAS  SPACETFACK CENTER  44  3317  503
ENT AFB COLORACC  E60    628-UPSI 1   SAT, NO, 503  ELEM   17  PAGE  1
COMPUTATIONS STAFTED AT REVOLUTION NO,    285N  VISUAL PASSES
```

REV NO,	ZEBRA DAY	TIME HR	MIN,	ELEV ANG,	AZIM ANG,	RANGE KM,	RATE KM/SEC	R.A. DEG,	DEC DEG	SUNS ELEV	ILLUMI NATION
3317	44	1	6,40	39.6	170,9	2981	-1.1	61,128	-11,327	-7,5	35,4
3317	44	1	7,40	44.3	162,0	2933	-.4	67,071	-5,468	-7,7	33,6
3317	44	1	8,40	48.1	151,6	2932	.3	73,043	,358	-7,9	31,8
3317	44	1	9,40	50.6	139,9	2975	1.0	79,001	5,939	-8,1	30,1
3325	45	1	47,40	40.9	208,4	2987	-2.2	44,130	-6,330	-15,3	35,7
3325	45	1	48,40	46.2	204,0	2871	-1.5	49,823	-,594	-15,5	33,9
3325	45	1	49,40	55.5	197,7	2798	-.8	55,831	5,356	-15,7	32,2
3325	45	1	50,40	62.4	188,3	2772	-.0	62,139	11,307	-15,8	30,5
3325	45	1	51,40	68.3	173,8	2791	.6	68,711	17,013	-16,0	28,8
3325	45	1	52,40	71.9	152,4	2853	1,3	75,486	22,250	-16,2	27,2
3325	45	1	53,40	72.4	127,4	2955	1,9	82,374	26,850	-16,4	25,7
3333	46	2	32,40	60.8	237,2	2959	-.5	51,080	20,514	-23,9	29,1
3333	46	2	33,40	66.6	240,0	2944	.0	57,266	26,046	-24,1	27,5
3333	46	2	34,40	76.2	241,7	2968	.7	63,950	31,223	-24,3	26,0
3348	48	0	41,40	35.5	184,1	2907	-2.2	48,178	-15,782	-1,9	43,8
3348	48	0	42,40	41.4	176,7	2797	-1.4	54,482	-9,844	-2,1	41,8
3348	48	0	43,40	46.9	167,[illegible]	2737	-.5	60,949	-3,647	-2,3	39,9
3348	48	0	44,40	51.4	155,4	2728	.2	67,526	2,550	-2,5	38,0
3348	48	0	45,40	54.2	141,8	2769	1.0	74,146	8,473	-2,7	36,2
3348	48	0	46,40	55.1	127,6	2856	1,8	80,732	13,883	-2,9	34,5
3348	48	0	47,40	54.4	114,4	2984	2.4	87,206	18,823	-3,1	32,7

```
COMPUTATIONS STCPPED AT REVOLUTION NO,    3355
NEXT REVCLLTION STARTS AT DAY    49,048  SAT, NO  503 ELEM  17
BT
>>>>>>>>NNNN
```

4.4.4 GROUND TRACK - GRNTRK

4.4.4.1 Purpose

The GRNTRK program computes a subsatellite track of a satellite between two specific revolutions at a given time increment.

4.4.4.2 Input - Schedule Tape Mode Only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-14	GRNTRK
		17	0 = Parameter card, E-file inputs
			1 = Parameter card and Element Set cards inputs
		18	0 = Hardcopy output
			1 = Hardcopy and TTY output
		80	J = Card type
5	Parameter Card		
		1-3	Satellite number
		20-24	Initial revolution (without Start Time)
		26-30	Final revolution (without End Time)
		32-34	Delta time interval (min.)
		37-46	Start time, YYMMDDHHMM (without Initial Rev.)
		49-58	End time, YYMMDDHHMM (without Final rev.)
		80	P = Card type
6	Data Cards:		

a Input Option 1

(1) Element Set Cards

Deck Position	Card Type	Column Number	Punch
7	End of Case Card		
8	End of Job Card		
9	End of Schedule Tape Card		
10	Blank Card		

4.4.4.3 Output

The output of the program is a printed ephemeris. The length is governed by the starting and final revolutions or starting and ending times on the input parameter card. The time interval between printed points is also variable and determined by the parameter card. Quantities printed are:

1. Epoch time
2. Time (year, month, day, hour, minutes)
3. Latitude in degrees
4. East longitude in degrees
5. Altitude in kilometers
6. Revolution number

SAMPLE PRINTOUT, GRNTRK

EPHEMERIS CALCULATIONS OCTOBER 28, 1963 PAGE 1

SATELLITE NO. 503 SATELLITE NAME: 62B-UPSI 1 TIME OF EPOCH 285.07472

YEAR	MONTH DAY	HOUR MIN.	LATITUDE DEGREES	LONGITUDE DEG. EAST	ALTITUDE KM.	REV. NO.
1963	OCT. 30	20 1.28	.0071569	213.6005291	76093.66935	2362
	OCT. 30	20 11.28	.5924843	211.6174115	76118.88303	2362
	OCT. 30	20 21.28	1.1574275	209.6340954	76138.10696	2362
	OCT. 30	20 31.28	1.7320779	207.6508125	76151.34232	2362
	OCT. 30	20 41.28	2.3064591	205.6677339	76158.58755	2362
	OCT. 30	20 51.28	2.8805286	203.6849700	76159.84188	2362
	OCT. 30	21 1.28	3.4544150	201.7027873	76155.10564	2362
	OCT. 30	21 11.28	4.0281012	199.7213208	76144.37694	2362
	NOV. 3	13 51.28	-.7234085	301.7370509	76052.65403	2363
	NOV. 3	14 1.28	-.1475698	299.7544221	76085.53270	2363

SATELLITE NO. 503 FINAL REVOLUTION NO. 2364

4.4.5 LOOK-ANGLE PROGRAM - LAP

4.4.5.1 Purpose

The LAP program computes a set of predicted acquisition coordinates for a given satellite and each specified sensor, using the nodal data in an element set. There are three sub-programs:

a. the General Look Angle Program - GLAP

b. the Baker-Nunn Look Angle Program - BLAP

c. the Special Look Angle Program - SLAP

4.4.5.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-27	LAP
		28-32	,DATA
5	Element Set Cards		
6	Alert Deck Request Card (optional)		
		1-3	Satellite number (right adjusted)
		5-7	Element Set number (right adjusted)
		20-24	Initial revolution for computation
		26-30	Final revolution for computation
		55	5 = Card type
7	LAP Request Card		
		1-3	Satellite number (not required if card is for Alert deck)
		5-7	Element number (must be -10 if card is for Alert deck)
		20-24	Initial revolution; or initial day number for SLAP (not required if card is for Alert deck)

Deck Position	Card Type	Column Number	Punch
		26-30	Final revolution; or final day number for SLAP (not required if card is for Alert deck)
		32-34	Time separation between points (optional for GLAP, SLAP; not required for BLAP) blank = 2 minutes
		36	0 or blank = All passes 1 = Visual passes
		37	0 = Short output format 1 = Long output format
optional for GLAP and SLAP, not required for BLAP		38-42	Maximum range, km (NM if GLAP and Col. 56 = 1) blank = 1×10^{10} km or N.M.
		43-45	Minimum elevation blank = 0°
		46-48	Maximum elevation blank = 90°
		49-51	Minimum azimuth blank = 0°
		52-54	Maximum azimuth blank = 360°
		55	0 = All-point GLAP 1 = One-point GLAP 3 = Three-point GLAP 4 = BLAP 8 = SLAP
		56	GLAP range units for output (optional) 0 = Kilometers 1 = Nautical miles
		56	BLAP Importance (optional 3, 2 or 1, where 3 is most important

Deck Position	Card Type	Column Number	Punch
		57	BLAP Reply (Optional)
			3, 2 or 1, where 3 is most urgent
		58	BLAP Element Indicator (optional)
			0 = New elements
			1 = Old elements
		66-72	Perigee distance (optional for BLAP, not required for GLAP, SLAP);
			q-term if $q \neq a$ (i-e);
			blank = q from element card
8	Sensor Card		

NOTE: Pairs of one Request card and one Sensor card are required for each sensor for which look angles are to be computed. These pairs constitute the Alert Deck if card 6 is used.

9	End of Data Card
10	End of Job Card
11	End of Schedule Tape Card
12	Blank Card

4.4.5.3 Output

The exact output obtained from the program depends upon the combination of options selected in the request card. The general output obtained depends on which of the three major subprograms (GLAP, SLAP, BLAP) is chosen in the LAP type option.

4.4.5.3.1 GLAP Output

The printout for this portion of the program contains:

1. Station and satellite numbers of the prediction
2. Station and satellite names
3. Element number
4. Acquisition data ordered by revolution and time within revolution:

a. Revolution number

b. Time of predicted point (GMT)

c. Elevation and azimuth in degrees

d. Range in kilometers

e. Optional elevation and illumination angles of the sun.

5. Day of next revolution, satellite number, and element number.
6. If computations were inconsistent, the residuals of time (min.), right ascension of ascending node (deg.), and height (km.) are printed.

The number of data lines per revolution number is determined by the type of GLAP requested.

1. One data line is put out for the point of closest approach in one-point GLAP.
2. Three data lines are produced in three-point GLAP. The first and third lines are for the points immediately above the minimum elevation angle of the station. The middle line is for the point of closest approach.
3. A variable number of data lines is produced by all-point GLAP, starting with the first point above the station horizon and proceeding by increments of delta time to the last point above the other horizon.

SAMPLE PRINTOUT, GLAP

BBBBBBBBBBBBBBBBBB 300 444

*

*

TRINIDAD 300 62B-KAPPA SAT. NO. 444 ELEM. 2*

COMPUTATIONS STARTED AT REVOLUTION NO. 32 ALL PASSES*

REV NO.	ZEBRA TIME DAY	HR	MIN	ELEV ANG.	AZIM ANG.	RANGE* KM *	
32	303	00	12.09	1.1	188.7	9534*	300
32	303	00	15.40	6.4	187.9	9139*	300
32	303	00	18.78	11.9	187.2	8723*	300
32	303	00	22.21	17.7	186.9	8290*	300
32	303	00	25.67	23.8	185.9	7844*	300
32	303	00	29.15	30.3	185.2	7389*	300
32	303	00	32.63	37.1	184.3	6932*	300
32	303	00	36.07	44.5	183.3	6482*	300
32	303	00	39.47	52.4	181.8	6048*	300
32	303	00	42.81	60.9	179.3	5643*	300
33	303	00	46.07	70.0	174.3	5280*	300
33	303	00	49.24	79.4	159.1	4974*	300
33	303	00	52.30	84.2	83.0	4740*	300
33	303	00	55.24	75.8	33.4	4591*	300
33	303	00	58.07	64.8	23.4	4535*	300
33	303	01	0.78	53.7	19.6	4572*	300
33	303	01	3.36	42.9	17.9	4695*	300
33	303	01	5.83	32.9	16.9	4893*	300
33	303	01	8.17	23.8	16.4	5151*	300
33	303	01	10.39	15.5	16.2	5454*	300
33	303	01	12.51	8.1	16.2	5788*	300
33	303	01	14.51	1.4	16.3	6144*	300
37	303	11	34.54	1.5	57.4	1459*	300
37	303	11	35.60	2.5	79.4	1439*	300
37	303	11	36.66	1.8	99.4	1613*	300
37	303	11	37.74	0.1	114.4	1931*	

COMPUTATIONS STOPPED AT REV. NO. 40*

NEXT REVOLUTION STARTS AT DAY 303.853 SAT 444 ELEM 2*$ 300

* MACHINE COMPUTATIONS CONSISTENT 300

4.4.5.3.2 SLAP Output

The Special Look Angle output is identical to GLAP output. Prediction points are separated by the delta time of the request card. Minimum elevation is not tested; instead, the iteration is continuous throughout the requested time interval.

4.4.5.3.3 BLAP Output

Baker-Nunn Look Angle output contains the following information:

1. Satellite name and number
2. Station name and number
3. Eight words of packed coded data plus a code number, station number code, and object number on the first line only. The eight words contain:
    a. year, month, day of culmination
    b. reply code
    c. azimuth angle in degrees and tenths of degrees
    d. altitude setting in degrees and tenths of degrees
    e. operational priority
    f. angular velocity in seconds of arc per second
    g. track angle of shadow entry or exit (hour of culmination, angle in degrees)
    h. time of culmination in minutes and seconds
    i. height in statute miles
    j. check sum word
4. Uncoded look angle data
    a. time of prediction point (GMT)
    b. elevation and azimuth in degrees
    c. angular velocity in seconds of arc per second
    d. slant range in miles
    e. height in miles
5. Day of next revolution, satellite number, and element number.
6. If computations were inconsistent, the residuals of time, right ascension, and height are printed.

SAMPLE PRINTOUT, BLAP

```
BBBBBBBBBBBBBBBBBB       220       444
  CAMERA STATION PREDICTIONS FOR 62B-KAPPA     *
  STATION AT EDW AFB CALIF(BN)   *
  NO VISUAL PASSES  SAT. NO.   444  REV.     32 TO    40*$

BBBBBBBBBBBBBBBBBB       721       444
  CAMERA STATION PREDICTIONS FOR 62B-KAPPA     *
  STATION AT COLD LAKE BAKER-NUN*
  *                                                               TIME          ALT     AZ    VEL   SR(MI,  HT(MI,
  11114 62000 21030 83775 01405 30375 03112 04112 01692 15395*  10 30 03 41.2  39.5   97.5  375.  2235.   1692.
              21030 83066 00812 30598 06109 01218 01450 42053*  10 30 06 12.3  81.2  306.6  598.  1462.   1450.
              21030 83423 00320 30623 08079 04629 00983 36867*  10 30 08 46.5  32.0  342.3  623.  1528.    983.
              21030 80204 00190 30856 110   02050 00540 44605*  10 30 11 20.8  19.0   20.4  856.  1206.    540.
  SAT. NO.   444 REV.    32 TO    40*
NEXT REVOLUTION STARTS AT DAY  303.853 SAT 444 ELEM   2*$            721
* MACHINE COMPUTATIONS CONSISTENT
```

EXPLANATIONS:

Line 9:

code no.
station code
yr.
satellite code
yr., month, day
reply code
priority
hrs.
min + sec. of cul.
check sum

11114 62000 21030 83775 01405 30375 03112 04112 01692 15395* 10 30 03 41.2 39.5 97.5 375. 2235. 1692.

Line 12:

azimuth angle
altitude
ang. vel.
track angle
ht. at cul.

21030 80204 00190 30856 11045 02050 00540 44605* 10 30 11 20.8 19.0 20.4 856. 1206. 540.

4.4.6 OBSERVING SCHEDULE - OBSERV

4.4.6.1 Purpose

The OBSERV program computes sets of predicted acquisition coordinates for fan and tracker type sensors. It is usually used for all satellites in the system over a specified sensor.

4.4.6.2 Input - Schedule Tape Mode Only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-14	ØBSERV
		17	0 = Parameter card, S-file and E-file tape inputs
			1 = Parameter card, Element Set cards and S-file tape inputs
			2 = Parameter card, Element Number cards and S-file and E-file tape inputs
			3 = Parameter card, Element Set cards and Sensor cards inputs
			4 = Parameter card, Sensor cards, Element Number cards and E-file tape inputs
		18	0 = Hardcopy and TTY output
			1 = Hardcopy output

Deck Position	Card Type	Column Number	Punch
5	Parameter Card		
		1-4	Sensor Number (rt. adj.)
		6-12	xxx.xxx (days) = Beginning time (days since beginning of year)
		13-19	xxx.xxx (days) = End time (days since beginning of year)
		20-25	xxxxxx = Maximum observable range
		26-29	xx.x$^{\circ}$ = Beam width
		30-33	Year
		34	0 = Fan number output (fans only)
			1 = Elevation angle output
		35	0 = Nautical units for range and range rate
			1 = CGS units for range and range rate
		37	0 = Unclassified
			1 = Confidential
			2 = Secret
			3 = Secret/NoForn
		38-39	Priority (printed on output message)
		53-56	Message number of first message to be generated
		79	R = Card type
		80	P = Card type
6	Fan Card (optional)		
		1-6	xxxx.x$^{\circ}$ = 1st fan elevation angle (or azimuth, if col. 77 is V-punched)
		7-12	xxx.xx$^{\circ}$ = 1st fan minimum azimuth (or elevation, if col 77 is V-punched)
		13-18	xxx.xx$^{\circ}$ = 1st fan maximum azimuth (or elevation, if col. 77 is V-punched)
		19-24	Fan number (rt. adj.)
		25-30	2nd fan (see cols. 1-6)

Deck Position	Card Type	Column Number	Punch
		31-36	2nd fan (see cols. 7-12)
		37-42	2nd fan (see cols. 13-18)
		43-48	Fan number (rt. adj.)
		49-54	3rd fan (see cols. 1-6)
		55-60	3rd fan (see cols. 7-12)
		61-66	3rd fan (see cols. 13-18)
		67-72	Fan number (rt. adj.)
		73-75	Sensor number
		77	V = Vertical fan indicator
		79	F = Card type
		80	P = Card type

NOTE: A maximum of seven fan cards may be input per sensor.

Deck Position	Card Type	Column Number	Punch
7	Tracker Card (optional)		
		2-6	-99.0 = tracker request
		19-24	xxx.xx^{o} = Minimum elevation
		25	3 = 3 points/pass
			5 = 5 points/pass
			7 = 7 points/pass
		73-75	Sensor number
		79	F = Card type
		80	P = Card type
8	Address Card		
		1-32	Sensor address (32 BCD characters)
		67-72	Sensor number
		79	A = Card type
		80	P = Card type

9 Data Cards

a. Input Option 0: None

b. Input Option 1:

(1) Element Set cards

Card Position	Card Type	Column Number	Punch
	c. Input Option 2:		
	(1) Element Number cards		
	d. Input Option 3:		
	(1) Sensor cards		
	(2) Element Set cards		
	e. Input Option 4:		
	(1) Sensor cards		
	(2) Element Number cards		
10	End of Case Card		
11	End of Job Card		
12	End of Schedule Tape Card		
13	Blank Card		

4.4.6.3 Output

Program printout consists of 4 parts.

4.4.6.3.2 Part 2

Part 2 contains a Satellite Summary for the receiving station and consists of the following information:

1. Satellite numbers.
2. Satellite number of any which are decaying.
3. Satellite numbers of any 100 days past epoch.
4. Element numbers

SAMPLE PRINTOUT, OBSERV

PART 2, SATELLITE SUMMARY

SAT. SUMMARY FOR STA-850
059,369,503
DECAYING
000
100 DAYS PAST EPOCH
000
SAT.NO./SET NO.
059/120 369/018 503/016

4.4.6.3.3 Part 3

Part 3 contains the teletype heading with priority, station name, message number classification, and current time.

4.4.6.3.4 Part 4

Part 4 contains the look angle schedule, sets of acquisition coordinates with the following information:

1. Satellite number
2. Element number
3. Time in hours, minutes, and hundredths of minutes
4. Elevation in degrees
5. Azimuth in degrees
6. Range and range rate in nautical or CGS units

SAMPLE PRINTOUT, OBSERV

PART 4, LOOK ANGLE SCHEDULE

UNCLAS SPACETRACK 308 0314.80
LOOK ANGLE SCHEDULE FOR POINT MUGU(FPS-1)

SAT	ELEM	TIME	ELEV	AZMTH	RANGE	R-RATE
DAY	305	01/11/63			(NM)	
369	18	1034.27	.9	58.1	1746	-1.5
369	18	1037.87	4.5	87.1	1569	-.0
369	18	1209.70	1.1	16.1	1711	-3.5
369	18	1216.96	64.2	100.2	494	-.0
369	18	1349.01	1.0	348.3	1713	-2.8
369	18	1354.70	14.8	296.3	1132	-.0
059	120	1405.47	1.0	187.1	1966	-1.9
059	120	1411.18	7.2	147.3	1599	-.0
DAY	306	02/11/63				
369	18	0102.21	10.8	266.5	1053	.0
503	16	0107.34	1.0	302.5	5962	-1.6
503	16	0147.65	67.6	130.2	1522	.0
503	16	0441.65	1.0	300.6	4265	-2.2
503	16	0501.24	10.4	230.0	2279	.0

4.4.7 POSITION SITUATION REPORT - PSR

4.4.7.1 Purpose

The PSR program computes satellite position information at a given time for the Position Situation Report, and computes satellite status information at a given time for the Satellite Situation Report.

4.4.7.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-11	PSR
		17	0 = Parameter card, I-file and E-file tape inputs
		18	0 = Hardcopy and TTY output
			1 = Hardcopy output
		80	J = Card type
5	Parameter Card (max.		= 11 cards for Satellite Situation Report)
		1	0 = Position Situation Report output
			1 = Satellite Situation Report output
			2 = Both reports output
		2-3	Hour of report
		4-5	Minutes of report
		6	Z = Zulu time (GMT)
		9-10	Day of month of report
		12-14	Month of report
		16-19	Year of report
		23	0 (or blank) = Suppress debris output in Satellite Situation Report
			1 = Output all satellite data in Satellite Situation Report

Deck Position	Card Type	Column Number	Punch
		24	0 (or blank) = Perigee and apogee in statute miles in Position Situation Report
			1 = Perigee and apogee in kilometers in Position Situation Report
		80	P = Card type
6	End of Case Card		
7	End of Job Card		
8	End of Schedule Tape Card		
9	Blank Card		

4.4.7.3 Output

4.4.7.3.1 Position Situation Report

The printout of the Position Situation Report gives the following quantities:

1. Object name
2. Satellite number
3. Latitude in degrees
4. West longitude in degrees
5. Inclination in degrees
6. Period in minutes
7. Apogee and perigee in kilometers or statute miles (as specified on the input parameter card)
8. Revolution number
9. T_N, L_N, Right Ascension$_N$ for this revolution
10. Classification (blank if unclassified)

4.4.7.3.2 Satellite Situation Report

The printout of the Satellite Situation Report consists of the following information:

Part 1 - Objects in orbit inclusive or exclusive of debris (option or input parameter card)

rt

1. Time of report
2. Satellite name and code name
3. Source
4. Launch date
5. Anomalistic period in minutes
6. Inclination in degrees
7. Apogee and perigee in statute miles
8. Transmitting frequency, if any
9. Comments from parameter cards

Part 2 - Objects removed from orbit

1. Satellite name and code name
2. Source
3. Launch date
4. Decay date

SAMPLE PRINTOUT, PSR

NON-CLASSIFIED

POSITION SITUATION REPORT PAGE 1

THE FOLLOWING INFORMATION COMPUTED FOR 0700Z 13 DEC 1963

OBJECT NAME	SAT NO	ELEM NO	LAT DEG	LONG W DEG	INCL DEG	PERIOD MIN	APOGEE K M	PERIGEE K M	REV NO	T SUB N DAYS	RA SUB N DEG	L SUB N DEG	ECC	CLASS
58ALPHA1	004	292	10	246	33.19	104.9	1638.6	341.6	25624	347.260	136.0	38.7	.088	
58BETA 2	005	128	-20	39	34.33	134.1	3936.4	660.7	22546	347.237	297.3	229.2	.189	
59ALPHA1	011	198	32	323	32.88	125.5	3283.5	567.6	20210	347.273	117.4	52.0	.164	
59ALPHA2	012	155	6	230	32.92	129.7	3683.8	538.7	18967	347.244	145.6	23.5	.185	
58BETA 1	016	140	34	147	34.26	138.5	4324.7	651.5	16979	347.261	315.4	219.9	.207	
59 ETA 1	020	144	-33	62	33.34	129.9	3764.9	472.9	7153	347.227	194.5	328.5	.194	
59IOTA 1	022	145	-27	313	50.31	101.2	1075.9	552.0	1665	347.229	257.2	256.3	.036	
59IOTA 2	023	146	-6	318	50.31	100.9	1055.7	550.8	1701	347.223	233.2	288.3	.035	
60ALPHA1	027			POSITION UNCERTAIN										
60BETA 1	028	116	39	277	48.39	99.1	737.2	607.8	9633	347.281	224.2	318.2	.003	
60BETA 2	029	128	49	226	48.38	99.2	748.3	694.0	9622	347.275	231.9	308.2	.004	
60GAMMA2	031	156	-32	275	51.30	94.1	602.9	346.4	0350	347.244	12.7	157.1	.019	
60EPSI 3	036	168	52	229	64.98	91.6	453.9	253.9	0262	347.270	174.1	4.4	.015	
60ZETA 1	043	148	-20	13	33.04	94.4	504.3	473.8	9823	347.233	205.9	319.2	.002	
60 ETA 1	045	111	-21	94	66.69	101.6	1055.6	611.2	7979	347.225	101.0	51.3	.031	
60 ETA 2	046	111	56	48	66.69	101.6	1053.4	611.0	17983	347.280	99.6	82.4	.031	
60 ETA 3	047	100	13	100	66.67	101.4	1034.7	611.1	8021	347.289	80.3	105.0	.029	
60IOTA 1	049	175	-47	9	47.25	114.8	1749.5	1145.3	5097	347.233	285.6	239.6	.039	
60IOTA 2	050	87	1	105	47.25	118.1	1680.1	1509.4	5121	347.291	50.0	106.1	.011	
60IOTA 3	051	83	47	8	47.23	118.3	1700.8	1504.6	4843	347.272	91.9	87.2	.012	
60IOTA 4	052			NO DATA IN EFILE										
60IOTA 5	053	81	-36	118	47.29	118.4	1688.8	1533.4	5598	347.221	109.5	51.3	.010	

SATELLITE SITUATION REPORT

THE FOLLOWING INFORMATION COMPUTED FOR 1200Z 20 APR 1964

PART 1 OBJECTS IN ORBIT PAGE 1

OBJECT		COMMON NAME	SOURCE	LAUNCH	PERIOD	INCL	APOGEE	PERIGEE	TRANS. FREQ
004	58ALPHA1	EXPLORER 1	US	1 FEB 58	104.7	33.18	999	213	
005	58BETA 2	VANGARD 1	US	17 MAR 58	134.0	34.23	2460	391	108.02
011	59ALPHA1	VANGARD 2	US	17 FEB 59	125.4	32.86	2040	347	
012	59ALPHA2	VANGARD 2 RCK	US	17 FEB 59	129.7	32.91	2285	333	
016	58BETA 1	VANGARD 1 RCK	US	17 MAR 58	138.4	34.28	2685	408	
020	59 ETA 1	VANGARD 3	US	18 SEP 59	129.8	33.34	2312	315	
022	59IOTA 1	EXPLORER 7	US	13 OCT 59	101.2	50.31	668	348	19.99
023	59IOTA 2	EXPLORER 7 RC	US	13 OCT 59	100.9	50.30	656	340	
027	60ALPHA1	PIONEER 5	US	11 MAR 60	311.6D	03.35DEG	.998 AU	.8061 AU	
028	60BETA 1	TIROS 1 RCKT	US	1 APR 60	99.1	48.39	463	427	
029	60BETA 2	TIROS 1	US	1 APR 60	99.2	48.41	463	431	

4.4.8 NODAL SYSTEM BULLETIN - SYSBULL

4.4.8.1 Purpose

The SYSBULL program corrects the orbital parameters affecting the time equation which describes the motion of a given satellite, and computes an ephemeris of future satellite positions with respect to the equator and other latitudes.

4.4.8.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-31	SYSBULL
		32-36	,DATA
5	Parameter Card		
		2	0 = Hardcopy output
			1 = Hardcopy and TTY output
		11	0 = Use nodal period in element set
			1 = Compute nodal period
6	Element Lead Card		
		8	7 = Card type
7	Element Set Cards		
NOTE:	From 1 to 25 element sets are allowed; there must be one for each Bulletin Request Card.		
8	Bulletin Request Lead Card		
		8	8 = Card type
9	Bulletin Request Card (all numbers right justified)		
		1-3	Satellite number
		4-6	Element Set number (only if elements are non-current)

Deck Position	Card Type	Column Number	Punch
NOTE:	Cols. 7-10 are used only if the elements are to be corrected.		
		7	Order of the least-squares equation
		8-9	Number of least-square points
		10	0 = Time equation correction
			1 = Right ascension equation correction
		11-13	Number of corrected element set
		14-18	Epoch revolution number of corrected element set
NOTE:	If cols. 11-18 are blank, no element set will be punched.		
		19-25	Perigee distance (earth radii), only if $q \neq a(1-e)$
		26-30	Initial revolution number for test bulletin
		31-35	Final revolution number for test bulletin
NOTE:	If cols. 26-35 are blank, no test bulletin will be output.		
		36	0 = Previous bulletin reference message for Part I output
			1 = List elements for Part I output
		37-39	Bulletin number for output
		40-44	Initial revolution for Part II output
		45-49	Final revolution for Part II output
NOTE:	If cols. 36-49 are blank, Bulletin Parts I and II will not be output.		
		50	0 = No grid (part III) output
			1 = Standard grid output
			2 = Special grid output
		51-55	Grid revolution number
		56-57	Minimum special grid latitude
		58-59	Maximum special grid latitude
		60-61	Special grid latitude increments
		62-65	Any special latitude (optional)
NOTE:	Cols. 56-65 are blank unless a special grid is requested.		

Deck Position	Card Type	Column Number	Punch
		66-67	Last two digits of the year for which computations are to be made
		68	0 = Hardcopy output
			1 = Hardcopy and TTY output
		69	0 = Unclassified output
			1 = Classified output
		70-72	Analyst number (optional)
		76-78	Day number (optional)

NOTE: The Element Lead, Element Set, Bulletin Request and Bulletin Request Card sets may be repeated as often as desired.

Deck Position	Card Type	Column Number	Punch
10	Least Squares Point Card		
		1-10	Delta t (days) or delta right ascension (degrees)
		11-20	Number of revolutions from epoch

NOTE: There is one least squares point on each Least Squares Point card, and the number of cards (points) appears in cols. 8-9 on the preceding Bulletin Request card.

Deck Position	Card Type	Column Number	Punch
11	Trailer Card (follows the last of the input sets)		
		8	9 = Card type
12	End of Date Card		
13	End of Job Card		
14	End of Schedule Tape Card		
15	Blank Card		

4.4.8.3 Output

The contents of output are determined by the bulletin request card and the option card. Maximum printed output consists of least squares correction, a test bulletin, the three parts of the edited bulletin, and an unedited bulletin.

4.4.8.3.1 Least Squares Option

A. Time equation correction

1. T_o, time at the node in days
2. P_n, nodal period in days/rev
3. C, rate of change of period in days/rev^2
4. d, rate of change of c in days/rev^3
5. least squares points from input (Δt_n, ΔN)
6. N by (N+1) matrix representing the normal equations of least square fit where N is the order of the curve
7. Computed increments for ΔT_o, ΔP_n, Δc, Δd
8. incremented elements

B. Right ascension correction

1. P_n
2. c
3. Ω, right ascension of ascending node in degrees
4. $\dot{\Omega}$, first derivative of Ω
5. $\ddot{\Omega}/2$, half of second derivative of Ω
6. least square points ($\Delta \Omega_n$, ΔN)
7. N by (N+1) matrix
8. Computed increments for $\Delta \Omega$, $\Delta\dot{\Omega}$, $\Delta\ddot{\Omega}/2$
9. incremented elements

If a nodal u-term was input, an anomalistic equation correction is output with the following quantities:

1. four points of (T_π , ΔN) where T_π is time of perigee in days
2. a 4 x 5 normal matrix
3. computed anomalistic equation with T_π , P_a (anomalistic period), C_a (anomalistic c- term), d_a (anomalistic d-term)

SAMPLE PRINTOUT, SYSBULL

LEAST SQUARES SECTION

SATELLITE 764 LEAST SQUARES.

0.75072060+002	0.61219440-001	-0.10992000-005	0.00000000+000

-0.000070000	0.	input points (Δt_n, ΔN)
0.007640000	9.	
0.008200000	10.	
0.010370000	14.	
0.010690000	15.	
0.011280000	16.	
0.012130000	18.	

N x (N+1) Matrix

0.70000000+001	0.82000000+002	0.11820000+004	0.17776000+005	0.60240000-001
0.82000000+002	0.11820000+004	0.17776000+005	0.27611400+006	0.85511000+000
0.11820000+004	0.17776000+003	0.27611400+006	0.43943920+007	0.12694410+002
0.17776000+005	0.27611400+006	0.43943920+007	0.71241042+008	0.19524863+003

-0.69864588-004	0.11549697-002	-0.40158214-004	0.75880680-006
0.75071990+002	0.62374410-001	-0.41257414-004	0.75880680-006-----corrected elements

SATELLITE 764 LEAST SQUARES FOR ANOMALISTIC EQUATION

76.082455730	-2.	T , N
76.3287883350	2.	
76.759835050	9.	
77.375571930	19.	

4 x 5 Matrix

0.40000000+001	0.28000000+002	0.45000000+003	0.75880000+004	0.30654665+003
0.28000000+002	0.45000000+003	0.75880000+004	0.13691400+006	0.21614670+004
0.45000000+003	0.75880000+004	0.13691400+006	0.25351480+007	0.34759773+005
0.75880000+004	0.13691400+006	0.25351480+007	0.47577450+008	0.58667894+006

0.76205621+002	0.61581912-003	-0.27264850-006	-0.96017112-009

EXPLANATIONS:

Line 2:

T_o	P_N	c	d
0.75072060+002	0.61219440-001	-0.10992000-005	0.00000000+000

Line 14:

ΔT_o	ΔP_N	Δc	Δd
-0.69864588-004	0.11549697-002	-0.40158214-004	0.75880680-006

Line 25:

T_π	P_a	c_a	d_a
0.76205621+002	0.61581912-003	-0.27264850-006	-0.96017112-009

4.4.8.3.2 Test Bulletin Option

1. revolution number (REV)
2. time at node computed from updated elements in days (TN NEW)
3. time at node from original elements in days (TN OLD)
4. difference between new and old times (DELTA T)
5. right ascension of ascending node from updated elements in degrees (RAN NEW)
6. right ascension of ascending node from old elements in degrees (RAN OLD)
7. difference in right ascensions (DEL RA)

SAMPLE PRINTOUT, SYSBULL

TEST BULLETIN SAT NO. 764 ELEM 4.

REV	TN NEW	TN OLD	DELTA T	RAN NEW	RAN OLD	DEL RA
53.	75.07199013	75.07206000	-0.00007	172.786	172.771	0.015
54.	75.13432404	75.13327834	0.00105	172.841	172.826	0.015
55.	75.19657999	75.19449448	0.00209	172.896	172.881	0.015
56.	75.25876253	75.25570842	0.00305	172.951	172.936	0.015
57.	75.32087621	75.31692017	0.00396	173.006	172.991	0.015
58.	75.38292559	75.37812971	0.00480	173.061	173.046	0.015
59.	75.44491522	75.43933707	0.00558	173.115	173.100	0.015
60.	75.50684965	75.50054222	0.00631	173.170	173.155	0.015
61.	75.56873344	75.56174517	0.00699	173.225	173.210	0.015
62.	75.63057114	75.62294592	0.00763	173.280	173.265	0.015
63.	75.69236729	75.68414448	0.00822	173.334	173.320	0.014
64.	75.75412646	75.74534083	0.00879	173.389	173.375	0.014
65.	75.81585320	75.80653499	0.00932	173.443	173.430	0.013
66.	75.87755205	75.86772695	0.00983	173.498	173.485	0.013
67.	75.93922758	75.92891671	0.01031	173.552	173.540	0.013
68.	76.00088433	75.99010438	0.01078	173.607	173.594	0.012
69.	76.06252686	75.05128964	0.01124	173.661	173.649	0.012
70.	76.12415972	76.11247281	0.01169	173.716	173.704	0.011
71.	76.18578746	76.17365378	0.01213	173.770	173.759	0.011

4.4.8.3.3 Edited Bulletin Option

4.4.8.3.3.1 Part I

1. Bulletin number
2. Satellite name
3. Epoch revolution
4. Epoch time in days
5. Anomalistic period in days/rev, (Pa)
6. First and second derivatives of the period (c, d)
7. Semi-major axis in earth radii, (a)
8. Eccentricity, (e)
9. Right ascension of the ascending node in degrees (Ω)
10. First derivative and one half of the second derivative of the right ascension of the ascending node, ($\dot{\Omega}$, $\ddot{\Omega}/2$)
11. Argument of perigee in degrees (ω)
12. First derivative and one half of the second derivative of argument of perigee ($\dot{\omega}$, $\ddot{\omega}/2$)
13. Mean longitude in degrees, (L)
14. Inclination in degrees, (i)

SAMPLE PRINTOUT, SYSBULL

EDITED BULLETIN, PART 1

Bulletin No. Sat. Name Epoch time P_a c d a e

```
     00     00
BBBBBBBBBBBBBBBB 764
BLTN  04 1964-12A      IN 3 PARTS. PART I.*
  071    76.18579 0.0615819  -0.273-006  -0.960-009  1.03227  0.00541*
 173.770  0.884     0.002    116.498  -4.229 -0.0007  186.87   95.70*
```

Epoch Rev Ω $\dot{\Omega}$ $\ddot{\Omega}/2$ ω $\dot{\omega}$ $\ddot{\omega}/2$ L i

4.4.8.3.3.2 Part II = For each crossing of ascending node

1. Date
2. Revolution number (REV)
3. Time in hours, minutes, hundredths of minutes (TIME Z)
4. Longitude west in degrees

SAMPLE PRINTOUT, SYSBULL

EDITED BULLETIN, PART 2

PART II. S-N EQUATOR CROSSINGS.*

	REV	TIME Z	LONG W	REV	TIME Z	LONG W	REV	TIME Z	LONG W*
16 MAR 64*									
	071	0427.63	66.91	072	0556.27	89.10	073	0725.02	111.30*
	074	0853.78	133.49	075	1022.56	155.69	076	1151.37	177.90*
	077	1320.21	200.12	078	1449.08	222.34	079	1618.00	244.58*
	080	1746.97	266.83	081	1916.01	289.09	082	2045.10	311.37*
	083	2214.27	333.67	084	2343.51	355.99*			
17 MAR 64*									
	085	0112.84	18.33	030	0242.26	40.69	087	0411.78	63.07*
	088	0541.40	85.49	089	0711.13	107.93	090	0840.98	130.39*

4.4.8.3.3.3 Part III - For a grid revolution

1. Direction of crossing
2. Latitude in degrees
3. Time in minutes } since crossing
4. West longitude in degrees } ascending node
5. Height above earth in kilometers
6. Visibility indicator
7. Argument of perigee
8. Latitude at perigee
9. Direction at perigee

SAMPLE PRINTOUT, SYSBULL

EDITED BULLETIN, PART 3

PART III. REDUCTION TO OTHER LATITUDES AND HEIGHTS FOR REV 83. *

LAT N	MINUTES PLUS	LONG CORR	HEIGHT KILOM	LAT S	MINUTES PLUS	LONG CORR	HEIGHT KILOM*
SN 00	0.00	0.00	254.8	NS 00	44.16	191.04	210.4 *
SN 10	2.49	1.62	245.8	NS 10	46.62	192.66	220.8 *
SN 20	4.97	3.31	237.6	NS 20	49.09	194.35	232.8 *
SN 30	7.45	5.14	230.4	NS 30	51.58	196.18	245.9 *
SN 40	9.93	7.26	233.9	NS 40	54.08	198.30	259.6 *
SN 50	12.42	9.89	218.2	NS 50	56.60	200.94	273.1 *
SN 60	14.92	13.62	213.1	NS 60	59.15	204.68	285.6 *
SN 70	17.45	20.17	208.4	NS 70	61.75	211.25	296.5 *
SN 80	20.15	39.25	203.6V	NS 80	64.52	230.35	305.3V *
N PT	22.17	95.55	200.3V	S PT	66.62	286.66	309.8V *
NS 80	24.20	151.84	197.2V	SN 80	68.71	342.97	312.3V *
NS 70	26.88	170.92	193.7	SN 70	71.50	2.08	312.4 *
NS 60	29.40	177.47	191.1	SN 60	74.11	8.65	309.4 *
NS 50	31.88	181.19	189.8	SN 50	76.68	12.39	303.9 *
NS 40	34.35	183.82	189.9	SN 40	79.23	15.04	296.4 *
NS 30	36.80	185.92	191.8	SN 30	81.76	17.16	287.5 *
NS 20	39.25	187.75	195.8	SN 20	84.28	19.01	277.9 *
NS 10	41.70	189.43	202.0	SN 10	86.79	20.70	268.0 *
NS 00	44.16	191.04	210.4	SN 00	89.24	22.32	258.4 *

GRID
SATELLITE 764 ELEMENTS 4. REVOLUTION NO. 83. DAY NO. 76.93

ARG OF PERIGEE = 166.49824 + (-4.22911) X (76.92658 - 76.18579)
= 113.36535
= 66.N GOING N-S.

4.4.8.3.4 Unedited Bulletin (not optional)

1. Revolution (REV)
2. Time at node in days (T SUB N)
3. Time at node in hours, minutes, hundredths of minutes (TIME Z)
4. Right ascension of ascending node in degrees (RA SUB N)
5. Longitude west in degrees (LONG)

SAMPLE PRINTOUT, SYSBULL

UNEDITED BULLETIN

UNEDITED BULLETIN NO. 04 SAT NO. 764 ELEM 4.

REV	T SUB N	TIME Z	RA SUB N	LONG
071	76.18479	0427.53	173.77019	66.91
072	76.24741	0556.27	173.82524	89.10
073	76.30905	0725.02	173.88019	111.30
074	76.37069	0853.78	173.93503	133.49
075	76.43234	1022.56	173.98978	155.69
076	76.49401	1151.37	174.04444	177.90
077	76.55570	1320.21	176.09900	200.12
078	76.61742	1449.08	174.15348	222.34
079	76.67917	1618.00	174.20789	244.58
080	76.74096	1746.97	174.26221	266.83
081	76.80279	1916.01	174.31646	289.09
082	76.86466	2045.10	174.37064	311.37
083	76.92658	22.1427	174.42476	333.67
084	76.98855	2343.51	174.47882	355.99
085	77.05059	0112.84	174.53281	18.33
086	77.11269	0242.26	174.58676	40.69
087	77.17485	0411.78	174.64065	63.08
088	77.23709	0541.40	174.69449	85.49
089	77.29940	0711.13	174.74829	107.93
090	77.36180	0840.98	174.80205	130.40

4.4.8.3.5 Punched Card Output Options

Punched card output consists of:

1. Seven and four-card element sets when an element update is made.
2. Look angle request card when an edited bulletin is requested (see section 4.4.5.1, card number 7.)
3. Edited bulletin when requested

4.4.9 X, Y, Z, COORDINATES LOOK ANGLE REPORT - XYZLA

4.4.9.1 Purpose

The XYZLA program computes sets of predicted acquisition coordinates for a given satellite and specified sensors, using ephemeris data from the MUNENDC or Interplanetary programs.

4.4.9.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-29	XYZLA
		30-34	,DATA
5	Parameter Card		
		1-4	Year of predictions
		5-7	Day of the year
		8-9	Hour of the day
		10-11	Minutes of the hour
		12-13	Seconds
		14-17	Starting time of predictions (thousandths of a second, col. 14 contains decimal point).
		25-34	Maximum time increment or range for predictions, in minutes from the starting time (Cols. 14-17). If blank, computations will cover all input ephemeris data.
		44	0 = Ephemeris data input by cards 1 = Ephemeris data input by tape

Deck Position	Card Type	Column Number	Punch
		45	0 = Compute all passes
			1 = Compute only visible passes
		46	0 = Positive elevations only acceptable
			1 = Positive and negative elevations acceptable
		47	1 = Output punched ephemeris cards
		48	0 = Topocentric output
			1 = Geocentric output (incl. day, time, right ascension, declination and range)
		49	0 = Topocentric output plus right ascension
			1 = Topocentric output plus hour angle
6	Sensor Card		
7	Satellite ID Card (required only when using ephemeris cards input)		
		1-16	Satellite name (alphanumeric)
8	Ephemeris Card (optional)		
		1-12	x geocentric coordinate (in earth radii)
		13-24	y geocentric coordinate (in earth radii)
		25-36	z geocentric coordinate (in earth radii)
		37-48	$\dot{x}$ geocentric coordinate
		49-60	$\dot{y}$ geocentric coordinate
		61-72	$\dot{z}$ geocentric coordinate
		73-80	Time increment (min.), from the starting time of predictions (parameter card, Cols. 14-17)

NOTE: Ephemeris cards are ordered by increasing time increment.

9	Blank Card (required for each tape or card input set)
10	Blank Card (required only for each card input set)
11	End of Data Card
12	End of Job Card
13	End of Schedule Tape Card
14	Blank Card

4.4.9.3 Output

The basic printout of this program is a schedule of predicted look angles for a particular station at specific times. The quantities printed are:

1. Satellite name
2. Station name
3. Data
   a. Day of year, hour, minute, and fraction of minute of the search point.
   b. Predicted right ascension, declination, azimuth, and elevation in degrees.
   c. Predicted slant range in kilometers.
   d. Elevation and illumination angles of the sun.

SAMPLE PRINTOUT, XYZLA

640402 VENUS *

LOOK ANGLES FOR BMEWS 3 FYLNGDALE*

DAY	TIME Z	R.A. DEG	DEC DEG.	AZIM ANG.	ELEV ANG.	RANGE KM.	SUNS ELEV	ILLUMI NATION
93	1124.73	87.111	-1.045	94.060	1.620	128967	39.9	103.5*
93	1204.73	87.194	-1.408	102.422	7.053	138587	40.7	103.4*
93	1244.73	87.225	-1.725	111.020	12.362	148121	40.1	103.3*
93	1324.73	87.215	-2.006	120.007	17.397	157603	38.2	103.3*
93	1404.73	87.175	-2.254	129.520	21.995	167063	35.2	103.3*
93	1444.73	87.113	-2.476	139.665	25.978	176524	31.2	103.2*
93	1524.73	87.037	-2.674	150.478	29.160	186010	26.6	103.2*
93	1604.73	86.954	-2.853	161.896	31.366	195536	21.4	103.2*
93	1644.73	86.870	-3.013	173.731	32.450	205116	15.9	103.2*
93	1724.73	86.791	-3.158	185.688	32.335	214758	10.2	103.1*
93	1804.73	86.721	-3.289	197.441	31.024	224467	4.4	103.1*
93	1844.73	86.664	-3.408	208.711	28.605	234243	-1.3	103.1*
93	1924.73	86.623	-3.516	219.330	25.221	244081	-6.9	103.1*
93	2004.73	86.600	-3.615	229.253	21.043	253977	-12.3	103.1*
93	2044.73	86.596	-3.705	238.530	16.244	263918	-17.2	103.1*
93	2124.73	86.612	-3.788	247.273	10.984	273892	-21.6	103.1*
93	2204.73	86.647	-3.865	255.626	5.406	283884	-25.2	103.1*

4.4.10 OTHER

The following programs in the Observation Acquisition area are seldom used by the analyst. A brief description of each program is given.

4.4.10.1 ORPS

The ORPS program is used for predicting search times for observing satellites at a given sensor. The program first computes the X,Y,Z search point coordinates of a satellite, then computes the right ascension, declination, azimuth, elevation, and slant range from these points in the same manner as the XYZLA program.

4.4.10.2 POSE

The POSE program computes a search ephemeris for a given station and a given point in space. The program is used when a sensor detects an unknown object. The assumption is made that if the object is a satellite it will come close to the same point in inertial space on the next revolution. Therefore, the look angles are calculated for the time, which is equal to the observation time plus the smallest orbital period expected. If the point is visible at the station, the quantities are written on the output tape.

The orbital time is then updated by a specified time increment and compared to the largest orbital period expected. If this period is within limits, the search ephemeris is computed for this new time.

4.4.10.3 PREPRINT

The purpose of PREPRINT is to supply the subsatellite point and related data of all satellites at a specified time. The west longitude and time of the last ascending node are also computed for each satellite. The following information is contained in the output:

a. Satellite name, number and element set number
b. Latitude and west longitude at report time
c. Inclination and period
d. Apogee and perigee
e. Eccentricity and height
f. Revolution number and time of ascending node, right ascension and longitude of the node.

4.5 INTERPLANETARY AREA

This section includes the interplanetary programs (HELIO, MUNENDC and NEAR).

4.5.1 HELIOCENTRIC - HELIO

4.5.1.1 Purpose

The HELIO program computes the heliocentric trajectory of a satellite given the launch and target points, the launch date and the flight time.

4.5.1.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-29	HELIO
		30-34	,DATA
5			
		5-6	01 = Card number
		10-11	Year of launch
		13-14	Month of launch
		16-17	Day of launch
6			
		5-6	02 = Card number
		10-17	Name of launch planet
7			
		5-6	03 = Card number
		10-17	Name of target planet (for an artificial body, use COMET)
8			
		5-6	04 = Card number
		10-13	xx.x (Days) = Time of launch increment

Deck Position	Card Type	Column Number	Punch
9			
		5-6	05 = Card number
		10-13	Number of time-of-launch increments
10			
		5-6	06 = Card number
		10-14	xxx.x (Days) = Initial time of flight
11			
		5-6	07 = Card number
		10-13	xxx.x (Days) = Time of flight increment
12			
		5-6	08 = Card number
		10-13	Number of transit time increments
13			
		5-6	09 = Card number
		10	0 = Initial value of sigma only
			1 = Long coast time only
			2 = Short coast time only
			3 = Short and long coast times
14			
		5-6	10 = Card number
		10-16	xxx.xxx^{o} = Initial sigma value
15			
		5-6	11 = Card number
		10-15	xx.xxx^{o} = Sigma increment
16			
		5-6	12 = Card number
		10-11	Number of sigma increments

Deck Position	Card Type	Column Number	Punch
17			
		5-6	13 = Card number
		10-18	xxxxx.xxx (km.) = The perifocal distance of the escape hyperbola taken equal to the earth-centered radius of the parking orbit.
18			
		5-6	14 = Card number
		10-16	9.0E+37 (km.) = Crossover factor in millions
19			
		5-6	15 = Card number
		10	0, Blank = Standard output 1 = Special output - ephemeris tape (Logical 7), hard copy of X Y and Z geocentric coordinates of the probe (earth radii) and X, Y, and Z heliocentric equatorial coordinates (A.U.) 2 = Same as Option 1 except: heliocentric coordinates are ecliptic, not equatorial 9 = Same as Option 1 plus: separation distance between target and present position on the transfer ellipse, and additional values describing the transfer ellipse and escape hyperbola
		12-14	xxx = Start time (days past injection)
		16-17	xx = Start time (hrs. past injection)
		19-20	xx = Start time (min. past injection)
		22-24	xxx = Stop time (days past injection)
		26-27	xx = Stop time (hrs. past injection)
		29-30	xx = Stop time (min. past injection)
		32-35	xxxx = Time interval (min.) between position computations

Deck Position	Card Type	Column Number	Punch
		37-38	xx = Launch date year (of selected transfer conic)
		40-41	xx = Launch date month (of selected transfer conic)
		43-44	xx = Launch date day (of selected transfer conic)
		46-50	xxx.x = Time of flight (days) of selected transfer conic
		52	1 = Long coast time
			2 = Short coast time
		54-57	xxxx = Maximum number of iterations (0000-9999) which the program will go through in calculating the eccentric anomaly for the present position on the hyperbola; if blank, the program assumes 200
20			
		5-6	15 = Card number
		10-16	xxx.xxx
		18-24	xxx.xxx
		26-32	xxx.xxx
		34-40	xxx.xxx
		42-48	xxx.xxx
		50-56	xxx.xxx
		58-64	xxx.xxx
		66-72	xxx.xxx

Selected azimuths to be processed up to a max. = 8

Deck Position	Card Type	Column Number	Punch	
		17	x	One of these columns must contain an "E" to indicate the last azimuth on the card
		25	x	
		33	x	
		41	x	
		49	x	
		57	x	
		65	x	
		73	x	
21				
		5-6	17 = Card number	
		10-18	zxxx.xxxx (sec.) = True anomaly in the hyperbolic orbit at injection	
22				
		5-6	18 = Card number	
		10-18	xxxxx.xxx (sec.) = Time from launch to parking-orbit injection	
23				
		5-6	19 = Card number	
		10-18	xxxxx.xxx (sec.) = Time of final burn	
24				
		5-6	20 = Card number	
		10-18	xxxx.xxxx° = The arc subtended at earth's center during ascent from launch to parking orbit	

Deck Position	Card Type	Column Number	Punch
25			
		5-6	21 = Card number
		10-18	xxxx.xxxx° = The arc subtended at earth's center during final burn out of the parking orbit to injection
26			
		5-6	22 = Card number
		10-18	xxxxx.xxx (sec./deg.) = The inverse parking orbital rate
27			
		5-6	23 = Card number
		10-18	xxxx.xxxx° = Longitude of launch site
28			
		5-6	24 = Card number
		10-18	xxxx.xxxx° = Latitude of launch site
		23-24	03 = This is last card in deck
			Blank = This is not last card in deck

NOTE: Cards numbered 25-36 will only be used when Card 3 has been designated as a COMET in cols. 10-18. Otherwise, Card number 24 is the last card in the deck.

Deck Position	Card Type	Column Number	Punch
29			
		5-6	25 = Card number
		10-24	.xxxxxxxxxxxxxx ($km.^3/sec.^2$) = Mean gravitation of the target body

Deck Position	Card Type	Column Number	Punch
30			
		5-6	26 = Card number
		10-18	xx.xxxxxx (A.U.) = Semi major axis of target body
31			
		5-6	27 = Card number
		10-16	.xxxxxx = Eccentricity of target body
32			
		5-6	28 = Card number
		10-17	x.xxxxxx (yr.) = Time change from 1950.0 to present date, for eccentricity (may be zero)
33			
		5-6	29 = Card number
		10-18	xx.xxxxxx$^\circ$ = Inclination to the ecliptic of the orbit of the target body
34			
		5-6	30 = Card number
		10-17	x.xxxxxx (yr.) = Time change from 1950.0 to present date, for inclination (may be zero)
35			
		5-6	31 = Card number
		10-19	xxx.xxxxxx$^\circ$ = Longitude of ascending node of the target body

Deck Position	Card Type	Column Number	Punch
36			
		5-6	32 = Card number
		10-17	xx.xxxxx (yr.) = Time change, from 1950.0 to present date, for node (may be zero)
37			
		5-6	33 = Card number
		10-19	xxx.xxxxxx° = Argument of perihelion for the target body
38			
		5-6	34 = Card number
		10-17	xx.xxxxx (yr.) = Time change, from 1950.0 to present date, of perihelion
39			
		5-6	35 = Card number
		10-18	xxxxxxx.x (Julian) = Date of perihelion passage of target body <u>minus</u> 2430000
40			
		5-6	36 = Card number
		10-14	COMET
		23-24	03 = This is last card in deck
41	End of Data Card		
42	End of Job Card		
43	End of Schedule Tape Card		
44	Blank Card		

4.5.1.3 Output

The normal program printout contains four parts. A special output option also may be included.

4.5.1.3.1 Part 1 - Input Conditions

This section contains the following quantities:

1. Greenwich hour angle in degrees (GHA)
2. Perifocal distance of the escape hyperbola in km. (PER)
3. True anomaly in the hyperbolic orbit at injection (TA)
4. Launch site latitude in degrees (LAA)
5. Launch site longitude in degrees (LOL)
6. Time from launch to parking orbit injection in seconds (T02)
7. Final stage burning time in seconds (T23)
8. Angle subtended at earth's center between launch and parking orbit injection in degrees (P02)
9. Angle subtended at earth's center during final stage burning (P23)
10. Inverse orbital rate during parking orbit coasting in seconds per degree (ORB)
11. Crossover distance in millions of km. (RS)
12. A.U. to million km. conversion factor (A.U.)
13. Gravitation constant for launch planet, $km^3/sec.^2$ (GML)
14. Gravitation constant for target planet, $km^3/sec.^2$ (GMT)

4.5.1.3.2 Part 2 - Heliocentric Conic Group

The second part of the printout contains the following quantities:

1. Flight time in days (TF)
2. Sun-to-launch-planet distance at launch time in A.U. (RL)
3. Sun-to-arrival-planet distance at arrival time in A.U. (RP)
4. Heliocentric central angle in degrees (HCA)
5. Semi-major axis of transfer ellipse in A.U. (SMA)
6. Eccentricity of transfer ellipse (ECC)
7. Communication distance at arrival in millions of km. (RC)

8. True anomaly in transfer ellipse at launch time in degrees (TAL)
9. True anomaly in transfer ellipse at arrival time in degrees (TAP)
10. Inclination angle of transfer ellipse to ecliptic plane in degrees (INC)
11. Celestial latitude at launch time in degrees (LAL)
12. Celestial latitude at arrival time in degrees (LAP)
13. Celestial longitude at launch time in degrees (LOL)
14. Celestial longitude at arrival time in degrees (LOP)
15. Speed at launch time in km./sec. (VL)
16. Path angle at arrival time in degrees (GAL)
17. Speed at arrival time in km./sec. (VP)
18. Path angle at arrival time in degrees (GAP)
19. Launch-planet speed at launch time in km./sec. (V1)
20. Arrival-planet speed at arrival time in km./sec. (V2)
21. Departure angle at launch time in degrees (DA)
22. Arrival angle at arrival time in degrees (AA)
23. Angle between launch hyperbolic excess velocity vector and launch planets orbital plane in degrees (GL)
24. Angle between launch hyperbolic excess velocity vector and arrival planets orbital plane in degrees (GP)
25. Sun-target planet-probe angle (Zeta P) in degrees (ZAP)
26. Sun-launch planet-probe angle (Zeta L) in degrees (ZAL)
27. Sun-launch planet-target planet angle (Eta) in degrees (ETA)
28. Distance of periapsis in km. (RCA)
29. Distance of apoapsis in km. (APO)
30. Period in days for the transfer ellipse (PRD)
31. Time of last theoretical perihelion passage (TAU)
32. Longitude of ascending node of transfer ellipse in degrees (LAN)
33. Argument of perihelion of transfer ellipse in degrees (AOP)

4.5.1.3.3 Part 3 - Planetocentric Conic Group

The third part of the printout contains the following quantities:

1. Hyperbolic excess speed at launch in km./sec. (VHL)
2. Declination of launch asymptote in degrees (DLA)
3. Right ascension of launch asymptote in degrees (RAL)
4. Hyperbolic excess speed at arrival in degrees (VPL)
5. Declination and right ascension of arrival asymptote in degrees (DPA,RAP)
6. Twice the total energy or vis viva in km.^{2}/sec.^{2} (C3)
7. Eccentricity (ECC)
8. Distance from launch planets center at injection in km. (RAD)
9. Injection speed in km./sec. (VEL)
10. Injection path angle in degrees (PTH)
11. Component of unit impact parameter in (T Bar) and (R Bar) directions (BT,BR)
12. Component in T and R directions of impact parameter in km. (B.T, B.R.)

4.5.1.3.4 Part 4 - Launch to Injection Conditions Group

The fourth part of the printout is composed of the following quantities:

1. Launch azimuth in degrees (LAZ)
2. Launch time in seconds past midnight of launch day (TL)
3. Injection time in seconds past midnight of launch day (TI)
4. Injection declination, right ascension, and launch azimuth in degrees (DEC, RA, AZ)
5. Parking orbit coast time in seconds (CST)
6. Time from launch to injection in seconds (TLI)
7. Angle between injection and the outgoing launch asymptote in degrees (CA)
8. Injection longitude in degrees (LON)
9. Latitude and longitude at start of final burning in degrees (LA2, LO2)
10. Launch and injection times in hours, minutes and seconds (TL, TI)

4.5.1.3.5 Part 5 - Geocentric and Heliocentric Position and Time

The part of the program printout is optional (see input parameters) and contains the following data:

1. Start time - year, day of year, month, day, seconds, and hundredths of seconds
2. For each position:
   a. Time in day of year, hours, minutes, seconds (TIME)
   b. Time in minutes relative to start time (DELTAT)
   c. x,y,z geocentric position of probe in earth radii (GEO)
   d. x,y,z heliocentric position in A.U. (HELIO)
3. Position and velocity components of injection point vector (X, Y, Z, XDOT, YDOT, ZDOT)

SAMPLE PRINTOUT, HELIO
NORMAL OUTPUT

LAUNCH DATE JUL 13 1962 DAY OF YEAR 194 JD 1858.5 ARRIVAL DATE DEC 9 1962

INPUT CONDITIONS

GHA	290.398	PER	6564.10	TA	3.700	LAL	28.317	LOL	279.457	TO2	438.878
T23	101.600	PO2	17.113	P23	8.240	ORB	14.6890	RS	0.		
AU	149.59900	GML	398603.199	GMT	324123.668						

HELIOCENTRIC CONIC EARTH TO VENUS

TF	149.00	RL	1.01654	RP	0.71951	HCA	161.936	SMA	0.8630	ECC	0.195369
RC	52.523	TAL	159.901	TAP	321.837	INC	2.976	LAL	-0.000	LAP	0.323
LOL	289.965	LOP	91.923	VL	26.7845	GAL	4.700	VP	37.9204	GAP	-5.974
V1	29.2964	V2	35.2066	DA	134.788	AA	67.428	GL	22.185	GP	-42.425
ZAP	50.794	ZAL	52.934	ETA	33.665	RCA	103.877	APO	154.321		
PRD	292.814	TAU	71.178	LAN	289.970	AOP	200.094				

PLANETOCENTRIC CONIC

VHL	3.7542	DLA	1.437	RAL	243.065	VPL	6.0073	DPA	-59.368	RAP	218.985
C3	0.14094	ECC	1.23209	RAD	6571.66	VEL	11.6363	PTH	2.042		
BT	-0.942789	BR	-0.333390	B.T	-16772.1	B.R	-0.0				

LAUNCH TO INJECTION CONDITIONS

LAZ	90.000	TL	73210.5	TI	77939.5	DEC	16.355	RA	98.733	AZ	66.558
CST	4128.52	TLI	4728.99	CA	140.555	LON	202.698	LA2	12.942	LO2	195.369
		TL	2020 10	TI	2138 59						

SAMPLE PRINTOUT, HELIO
OPTIONAL PORTION

INJECTION POINT VECTOR (IN EARTH RADII AND EARTH RADII PER KEMIN)

X -0.084545 Y 0.550397 Z 0.866897 XDOT -1.26349945 YDOT -0.66355073 ZDOT 0.36041732

1962194213859.453

TIME	DELTA T	XGEO	YGEO	ZGEO	XHELIO	YHELIO	ZHELIO
194 21 38 59	0.	-0.159483	0.974895	0.294229	54.0599001	30.3926111	56.5468080
195 3 38 59	360.0	-10.426584	-14.930659	1.814374	54.5845891	30.2850460	56.4464537
195 9 28 59	720.0	-17.222961	-28.064536	2.245881	55.1304474	30.1575102	56.3520662
195 15 38 59	1080.0	-23.631991	-40.575107	2.623215	55.6777991	30.0237506	56.2570300
195 23 38 59	1440.0	-29.868719	-59.795400	2.981150	56.2252565	29.8858550	56.1611316
195 5 38 59	1800.0	-36.009148	-64.842407	3.329171	56.7723414	29.7445901	56.0643133

4.5.2 UNIFIED ENCKE WITH DIFFERENTIAL CORRECTION - MUNENDC

4.5.2.1 Purpose

The MUNENDC program computes a satellite's predicted position and velocity with respect to the Earth, Moon and Sun for specified time intervals given the satellite's position and velocity at a starting time.

4.5.2.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-31	MUNENLC
		32-36	,DATA
5	Parameter Card 1		
		1-4	Year of epoch
		5-6	Month of epoch
		7-8	Day of epoch
		9-10	Hour of epoch
		11-12	Minutes of epoch
		13-18	xx.xxx = Seconds of epoch
		25-40	Satellite name
6	Parameter Card 2		
		1-12	x geocentric coordinate of initial position (in earth radii)
		13-24	y geocentric coordinate of initial position (in earth radii)
		25-36	z geocentric coordinate of initial position (in earth radii)

Deck Position	Card Type	Column Number	Punch
		37-48	$\dot{x}$ geocentric coordinate of initial velocity (in earth radii/k_e^{-1} min.)
		49-60	$\dot{y}$ geocentric coordinate of initial velocity (in earth radii/k_e^{-1} min.)
		61-72	$\dot{z}$ geocentric coordinate of initial velocity (in earth radii/k_e^{-1} min.)

NOTE: All quantities on this card are given in floating point format = $\pm$xxxxxxxx$\pm$xx. The decimal point is assumed at the right of the mantissa.

Deck Position	Card Type	Column Number	Punch
7	Parameter Card 3		
		1-10	Runge-Kutta error criterion for position
		11-20	Runge-Kutta error criterion for velocity
		21-24	Year of initial time of ephemeris
		25-26	Month of initial time of ephemeris
		27-28	Day of initial time of ephemeris
		29-30	Hours of initial time of ephemeris
		31-32	Minutes of initial time of ephemeris
		33-38	xx.xxx = Seconds of initial time of ephemeris
		39-42	Year of final time of ephemeris
		43-44	Month of final time of ephemeris
		45-46	Day of final time of ephemeris
		47-48	Hours of final time of ephemeris
		49-50	Minutes of final time of ephemeris
		51-56	xx.xxx = Seconds of final time of ephemeris
		57-67	Initial integration step size, Δt (min.), (decimal anywhere in field)
		68	0 = variable Δt 1 = fixed Δt
		69	0 = Do not print moon satellite number 1 = Print moon satellite number
		70	0 = Print every 42 lines

Deck Position	Card Type	Column Number	Punch
8	Parameter Card 4		
		1	0 = Do not correct Encke element $\tilde{M}_o$
			1 = Correct Encke element $\tilde{M}_o$
		2	0 = Do not correct Encke element 1/a
			1 = Correct Encke element 1/a
		3	0 = Do not correct Encke element c*
			1 = Correct Encke element c*
		4	0 = Do not correct Encke element s*
			1 = Correct Encke element s*
		5	0 = Do not correct Encke element α^*
			1 = Correct Encke element α^*
		6	0 = Do not correct Encke element δ^*
			1 = Correct Encke element δ^*
		20	Correction iteration (any number from 1 to 9)
		25-30	Absolute maximum of observation residuals in kms.
		31-36	Absolute maximum of range rate residuals in km/sec.
		37-40	Rejection parameter.
9	Observation Cards		
10	End Card		
11	Sensor Cards		
12	End Card		
13	End of Data Card		
14	End of Job Card		
15	End of Schedule Tape Card		
16	Blank Card		

4.5.2.3 Output

The printed output for MUNENDC contains two parts.

4.5.2.3.1 Part 1, Ephemeris Output

4.5.2.3.1.1 Page 1

The quantities printed on Page 1 are:

1. t_0 (TIME SUB 0)
2. displacement error (DISPLACE ERROR)

3. displacement rate error (DIS.RATE ERROR)
4. Δ t (DELTA TIME)
5. semi-latus rectum (PARAMETER)
6. e (ECCENTRICITY)
7. q, perifocal distance (Q)
8. $\tilde{M}_0$ (M-O-TILDE)
9. 1/a (ONE OVER A)
10. $\underline{P}$ components (PX, PY, PZ)
11. $\tilde{\underline{Q}}$ components (QX-TILDE,QY-TILDE,QZ-TILDE)
12. Time (TIME)
13. x,y, and z components of position displacement from the reference orbit (XSI, ETA, ZETA)
14. x,y, and z components of velocity displacement from the reference velocity (LAMDA, OMEGA, PSI)
15. first 12 points from lunar and solar ephemerides tapes.

4.5.2.3.1.2 <u>Page 2</u>

The quantities on this page are a printout of the elements identical to Page 1. Since the first page appears only after initialization, this page is necessary to show the elements after rectification.

4.5.2.3.1.3 <u>Pages 3 and 4</u>

These pages describe the first two time points of the ephemeris. The items printed are:

1. geocentric position, velocity, and distance for the reference orbit
2. same for the vehicle in its actual trajectory
3. geocentric position vectors of the moon and the sun
4. position vectors and distances of the moon and the sun from the vehicle
5. position and velocity deviations from the reference orbit
6. magnitude, radial, and tangential components of the velocity vector; the time interval
7. perturbative accelerations; distance of the vehicle above earth's equator; other intermediate quantities

8. position and velocity of the actual vehicle from the earth in laboratory units.

At the point of closest approach to the moon the full page output will again be printed for that point. The comment "THIS PAGE CONTAINS A POINT OF CLOSEST APPROACH TO THE MOON" is printed at the bottom of the page.

At the point at which rectification occurs the full page output appears twice. The first page will have the points before rectification. The comment "THIS IS THE POINT AT WHICH RECTIFICATION OCCURS" will appear at the bottom of the page. The second full page printout will be the first point of the new reference orbit.

This type of output will also be given after 42 or 10 integration steps (input option).

4.5.2.3.1.4 Page 5 and 6

For the remainder of the ephemeris computation, only one line per time point is given containing:

1. time (TIME)
2. geocentric coordinates of position (X,Y,Z EARTH-ROCK, G-RADII)
3. coordinates of velocity (X,Y,Z DOT ER)
4. geocentric distance (R EARTH-ROCK, G-RADII)

If the option to print moon-satellite coordinates is used, the next page will be one line per point consisting of:

1. time (TIME)
2. coordinates of moon-satellite position (X,Y,Z MOON-ROCKET, G-RADII)
3. coordinates of sun-satellite position (X,Y,Z SUN-ROCKET, G-TADII)
4. distance of object from moon (R MOON-ROCKET, G-RADII)

SAMPLE PRINTOUT, MUNENDC

EPHEMERIS, PAGE 1

UNIFIED ENCKE WITH DIFFERENTIAL CORRECTION FOR RANGER 6 FINAL
UNIFIED ENCKE OUTPUT

PAGE= 1

TIME SUB 0	DISPLACE ERROR	DIS.RATE ERROR	DELTA TIME	PARAMETER	ECCENTRICITY	Q	
6401310838.35	-.399999999-4	+.099999999-4	+.199999999+2	+.203115513+1	+.97940174234	+.102614597+1	
M-U-TILDE	**ONE OVER A**	**PX**	**PY**	**PZ**	**QX-TILDE**	**QY-TILDE**	**QZ-TILDE**
+.753790052+2	-.200734185-1	+.94689813023	+.30268747283	+.10846305337	-.44933041254	+.115132245-1	+.70972806337
TIME	**XSI**	**ETA**	**ZETA**	**LAMDA**	**OMEGA**	**PSI**	
6401310838.35	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	-.00000000002	

TIME-ET	X MOON MIDNT	Y MOON MIDNT	ZMOON MIDNT	X MOON NOON	Y MOON NOON	Z MOON NOON
640130	-.405429609+2	+.314104491+2	+.174903341+2	+.507924281+2	+.260196264+2	+.156758513+2
640131	-.543361000+2	+.202717779+2	+.136448042+2	+.571388543+2	+.142528530+2	+.114293124+2
640201	-.591776186+2	+.804927150+1	+.906287856+1	+.604407061+2	+.174644634+1	+.657969204+1
640202	-.609270274+2	-.457243303+1	+.401407628+1	+.606451633+2	-.108273444+2	+.140000404+1
640203	-.596123916+2	-.169421370+2	-.122931709+1	+.578537881+2	-.225450494+2	-.384171341+1
640204	-.554012888+2	-.284690189+2	-.640628027+1	+.522929871+2	-.337519114+2	-.889355404+1
640205	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002
640206	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002
640207	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002
640208	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002
640209	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002
640210	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002	+.00000000002

TIME-ET	X OF SUN	Y OF SUN	Z OF SUN
640130	+.145697154+5	+.164307051+5	+.712510096+4
640131	+.148867568+5	+.161934886+5	+.702222021+4
640201	+.151992249+5	+.159512738+5	+.691717743+4
640202	+.155070286+5	+.157041306+5	+.680999618+4
640203	+.158100720+5	+.154521266+5	+.670071421+4
640204	+.161082840+5	+.151953349+5	+.658935967+4
640205	+.00000000002	+.00000000002	+.00000000002
640206	+.00000000002	+.00000000002	+.00000000002
640207	+.00000000002	+.00000000002	+.00000000002
640208	+.00000000002	+.00000000002	+.00000000002
640209	+.00000000002	+.00000000002	+.00000000002
640210	+.00000000002	+.00000000002	+.00000000002

SAMPLE PRINTOUT, MUNENDC

EPHEMERIS, PAGE 3

UNIFIED ENCKE WITH DIFFERENTIAL CORRECTION FOR RANGER 6 FINAL PAGE= 3

UNIFIED ENCKE OUTPUT

TIME	XE	YE	ZE	X DOT E	Y DOT E	Z DOT E	RE
	G-RADII	G-RADII	G-RADII	G-RAD/KEMAN	G-RAD/KEMAN	G-RAD/KEMAN	G-RADII
6401310858,35	-,266169991-2	-,462113469?7	+,188090830+1	+,228565868003	-,500362620+1	+,126452129+1	+,266740255+2
TIME	X EARTH-ROCK	Y EARTH-ROCK	Z EARTH-ROCK	X DOT ER	Y DOT ER	Z DOT ER	R EARTH-ROCK
	G-RADII	G-RADII	G-RADII	G-RAD/KEMAN	G-RAD/KEMAN	G-RAD/KEMAN	G-RADII
6401310858,35	-,266169990-2	-,462113469??	+,188090830+1	-,228565860003	-,500362620+1	+,126452129+1	+,266740255+2
TIME	X EARTH-MOON	Y EARTH-MOON	Z EARTH-MOON	X EARTH-SUN	Y EARTH-SUN	Z EARTH-SUN	R DOT E
	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII	G-RAD/KEMAN
6401310858,35	-,965028941+2	-,157921970+2	+,120030105+2	+,150071145+5	-,161035185+5	-,698320131+4	+,228147220??
TIME	X MOON-ROCKT	Y MOON-ROCKT	Z MOON-ROCKT	X SUN-ROCKET	Y SUN-ROCKET	Z SUN-ROCKET	R MOON-ROCKT
	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII
6401310858,35	+,298850951+2	+,162543105+2	+,136847208+2	+,150307315+5	+,161030544+5	-,698152041+4	+,366693480+2
TIME	XBI	ETA	ZETA	XBI DOT	ETA DOT	ZETA DOT	PERTUR-DISPL
	G-RADII	G-RADII	G-RADII	G-RAD/KEMAN	G-RAD/KEMAN	G-RAD/KEMAN	G-RADII
6401310858,35	+,00000000002	+,00000000002	+,00000000002	+,00000000002	+,00000000002	+,00000000002	+,00000000002
TIME	RE	R EARTH-ROCK	R MOON-ROCKT	R SUN-ROCKET	R EARTH-MOON	R EARTH-SUN	R TILDE
	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII	G-RADII	RADIAN
6401310858,35	+,266740255+2	+,266740255+2	+,366693480+2	+,221078532+5	+,598837389+2	+,230913793+5	+,753790052+2
TIME	R DOT E	R DOT E-R	RV DOT E-R	R DOT	PERTUR-RATE	DELTA T	U TILDE
	FEET/SECOND	FEET/SECOND	FEET/SECOND	FEET/SECOND	G-RAD/KEMAN		G-RADII
6401310858,35	-,991730432+4	+,591730432+4	+,138577175+4	+,607740918+4	-,00000000002	+,799999999-2	+,690029507+2
TIME	X DOT GRAV	Y DOT GRAV	Z DOT GRAV	UZ PRIM	X TILDE	G	FOFG
	G-RAD/KEMAN	G-RAD/KEMAN	G-RAD/KEMAN		G-RADII		
6401310858,35	-,436067050-5	+,400924646-5	+,317264635-5	-,630160713-1	-,759871910+1	+,00000000002	+,118415321-9
TIME	X EARTH-ROCK	Y EARTH-ROCK	Z EARTH-ROCK	X DOT ER	Y DOT ER	Z DOT ER	R EARTH-ROCK
	NAUT-MILES	NAUT-MILES	NAUT-MILES	FEET/SECOND	FEET/SECOND	FEET/SECOND	NAUT-MILES
6401310858,35	-,918886788+3	-,159181418+4	+,578903137+4	-,592816281+4	-,129775759+4	+,327970567+3	+,918650771+5

SAMPLE PRINTOUT, MUNENDC

EPHEMERIS, PAGES 5 AND 6

UNIFIED ENCKE WITH DIFFERENTIAL CORRECTION FOR RANGER 6 FINAL PAGE. 5

UNIFIED ENCKE OUTPUT

TIME	X EARTH-ROCK G-RADII	Y EARTH-ROCK G-RADII	Z EARTH-ROCK G-RADII	X DOT ER G-RAD/KEMAN	Y DOT ER G-RAD/KEMAN	Z DOT ER G-RAD/KEMAN	R EARTH-ROCK G-RADII
6401311018.35	-.279528605+2	-.75922147813	+.160415073+1	+.22064673046	-.498339296-1	+.131437259-1	+.280091436+2
6401311138.35	-.292438072+2	-.105495630+1	+.158467772+1	+.21344627137	-.495774054-1	+.135612248-1	+.293029227+2
6401311258.35	-.304937558+2	-.134904000+1	+.144298006+1	+.20685010531	-.492808431-1	+.139141448-1	+.305576679+2
6401311418.35	-.317060475+2	-.164126631+1	+.135922309+1	+.20077414350	-.489544339-1	+.142149946-1	+.317779816+2
6401311538.35	-.328835638+2	-.193148691+1	+.127386658+1	+.19514901132	-.486056077-1	+.144734718-1	+.329648820+2
6401311658.35	-.340288128+2	-.221956750+1	+.118707899+1	+.18991809134	-.482398270-1	+.146972232-1	+.341217780+2
6401311818.35	-.351439963+2	-.250543782+1	+.109904804+1	+.18503465533	-.478611255-1	+.148923744-1	+.352503277+2
6401311938.35	-.362310626+2	-.278902432+1	+.100998858+1	+.18045981187	-.474724798-1	+.150639076-1	+.363522835+2
6401312058.35	-.372917475+2	-.307027464+1	+.91984849516	+.17616083536	-.470760665-1	+.152159372-1	+.374292284+2
6401312218.35	-.383276075+2	-.334914749+1	+.82891327101	+.17211007588	-.466734480-1	+.153519140-1	+.384825855+2

UNIFIED ENCKE WITH DIFFERENTIAL CORRECTION FOR RANGER 6 FINAL PAGE. 6

TIME	X MOON-ROCKT G-RADII	Y MOON-ROCKT G-RADII	Z MOON-ROCKT G-RADII	X SUN-ROCKET G-RADII	Y SUN-ROCKET G-RADII	Z SUN-ROCKET G-RADII	R MOON-ROCKT G-RADII
6401311018.35	+.288360836+2	-.158750172+2	+.133561708+2	+.150494521+5	+.160893280+5	+.697577316+4	+.355239983+2
6401311138.35	+.278217952+2	-.154919285+2	+.130229776+2	+.150681136+5	+.160755875+5	+.697002198+4	+.344042125+2
6401311258.35	+.268389288+2	-.151048744+2	+.126856146+2	+.150867198+5	+.160618334+5	+.696426649+4	+.333079091+2
6401311418.35	+.258842185+2	-.147137816+2	+.123444795+2	+.151052741+5	+.160480629+5	+.695850623+4	+.322315733+2
6401311538.35	+.249548240+2	-.143186061+2	+.119999025+2	+.151237764+5	+.160342850+5	+.695274103+4	+.311731166+2
6401311658.35	+.240482211+2	-.139193386+2	+.116521590+2	+.151422380+5	+.160204910+5	+.694697065+4	+.301303421+2
6401311818.35	+.231621918+2	-.135160021+2	+.113014835+2	+.151606524+5	+.160066840+5	+.694119488+4	+.291014256+2
6401311938.35	+.222947719+2	-.131086641+2	+.109480779+2	+.151790242+5	+.159928639+5	+.693541359+4	+.280847706+2
6401312058.35	+.214442097+2	-.126973816+2	+.105921168+2	+.151973553+5	+.159790310+5	+.692962664+4	+.270789692+2
6401312218.35	+.206089325+2	-.122822303+2	+.102337527+2	+.152156473+5	+.159651852+5	+.692383394+4	+.260827716+2

4.5.2.3.2 Part 2, Differential Correction Output (not currently used)

4.5.2.3.2.1 Section 1

This section contains the residuals printed in tabular form. The quantities are:

1. sensor (STAT)
2. time (TIME)
3. range residual (RHO RESID)
4. range rate residual (RODOT RESID)
5. right ascension residual (R.A. RESID)
6. declination residual (DECL RESID)
7. azimuth residual (AZIM RESID)
8. elevation residual (ELEV RESID)

An asterisk appears next to residuals which are rejected.

4.5.2.3.2.2 Section 2

This section contains corrections made to auxiliary quantities which are translated by the program to element corrections:

1. RMS value of residuals in position (SUM)
2. $\Delta \tilde{M}_0$ (DEL M-O-TIL)
3. $\Delta (1/a)$ (DELTA 1/A)
4. Δc^* (DELTA C*)
5. Δs^* (DELTA S*)
6. $\Delta \alpha^*$ (DELTA ALPHA*)
7. $\Delta \delta^*$ (DELT DELTA*)

4.5.2.3.2.3 Section 3

This section contains the corrected elements and the position and velocity coordinates (at t_0) listed as follows:

1. $\tilde{M}_0$ (M-O-TILDE)
2. $1/a$ (ONE OVER A)
3. $\underline{P}$ components (PX, PY, PZ)
4. $\underline{\tilde{Q}}$ components (QX-TILDE, QY-TILDE, QZ-TILDE)

4.5.3 NEAR-EARTH CONIC - NEAR

4.5.3.1 Purpose

The NEAR program computes possible trajectories for lunar flights and other missions in which the probe remains within the Earth's sphere of influence. The powered flight phases are based on a configuration involving an initial burn time, a circular intermediate parking orbit coasting phase and a final burn time terminating in injection into the transfer conic. The transfer conic solutions include escape trajectories of both elliptical and hyperbolic form depending upon the magnitude of the energy expended during the final burning stage.

Given launch point, launch azimuth and arrival date, the program computes launch time, injection point into the transfer conic, time of flight, coast time and other trajectory properties.

4.5.3.2 Input - Schedule Tape Mode (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		17-19	RUN
		25-31	NEARBBA
		32-36	,DATA

Deck Position	Scaling Factor	Column Number	Punch
5			
	F2.0	5-6	01 = Card number
	F2.0	10-11	Last 2 digits of year of launch (optional)
	F2.0	13-14	Month of launch (optional)
	F2.0	16-17	Day of launch (optional)

Deck Position	Scaling Factor	Column Number	Punch
6			
	F2.0	5-6	02 = Card number
	F2.0	10-11	Last 2 digits of year of arrival
	F2.0	13-14	Month of arrival (optional)
	F2.0	16-17	Day of arrival (optional)
7			
	F2.0	5-6	03 = Card number
	F2.0	10-11	Time of flight (optional)
	I2	13-14	Number of arrival dates (optional)
	F3.0	16-18	Minimum allowable coast time (optional)
8			
	F2.0	5-6	04 = Card number
	F6.2	10-15	Initial launch azimuth
	F5.1	17-21	Perigee distance (km.) (optional) (if given, the program will compute eccentricity)
9			
	F2.0	5-6	05 = Card number
	F3.1	10-12	Azimuth increment
	F5.1	14-18	Azimuth used to compute the energy term (optional) (if 7777., program assumes = 102°)
10			
	F2.0	5-6	06 = Card number
	I2	10-11	Number of azimuth increments
	I1	13	1 = Use short coast time 2 = Use long coast time 3 = Use both coast times
	F8.2	15-22	Distance from earth's center to injection into transfer conic (meters) (optional)

Deck Position	Scaling Factor	Column Number	Punch
11			
	F2.0	5-6	07 = Card number
	F7.4	10-16	Angle between perigee and injection
12			
	F2.0	5-6	08 = Card number
	F8.3	10-17	Time from launch to injection
13			
	F2.0	5-6	09 = Card number
	F8.3	10-17	Time during final burn
14			
	F2.0	5-6	10 = Card number
	F8.4	10-17	Angle from launch to injection into parking orbit
15			
	F2.0	5-6	11 = Card number
	F8.4	10-17	Angle made during final burn
16			
	F2.0	5-6	12 = Card number
	F9.6	10-18	Inverse parking orbital rate (sec./deg.)
17			
	F2.0	5-6	13 = Card number
	F4.0	10-13	Longitude of launch point (deg.)
	F2.0	15-16	Longitude of launch point (min.)
	F4.2	18-21	Longitude of launch point (sec.)

Deck Position	Scaling Factor	Column Number	Punch
18			
	F2.0	5-6	14 = Card number
	F4.0	10-13	Latitude of launch point (deg.)
	F2.0	15-16	Latitude of launch point (min.)
	F4.2	18-21	Latitude of launch point (sec.)
19			
	F2.0	5-6	15 = Card number
	F3.0	10-12	Lunar longitude (deg.) (optional)
	F2.0	14-15	Lunar longitude (min.) (optional)
	F4.2	17-20	Lunar longitude (sec.) (optional)
20			
	F2.0	5-6	16 = Card number
	F3.0	10-12	Declination of outgoing asymptote (deg.) (optional)
	F2.0	14-15	Declination of outgoing asymptote (min.) (optional)
	F4.2	17-20	Declination of outgoing asymptote (sec.) (optional)
21			
	F2.0	5-6	17 = Card number
	F3.0	10-12	Greenwich hour angle at launch (deg.) (optional)
	F2.0	14-15	Greenwich hour angle at launch (min.) (optional)
	F4.2	17-20	Greenwich hour angle at launch (sec.) (optional)

Deck Position	Scaling Factor	Column Number	Punch
22			
	F2.0	5-6	18 = Card number
	F2.0	10-11	Right ascension of outgoing asymptote (hrs.) (optional)
	F2.0	13-14	Right ascension of outgoing asymptote (min.) (optional)
	F4.2	16-19	Right ascension of outgoing asymptote (sec.) (optional)
23			
	F2.0	5-6	19 = Card number
	F7.6	10-16	X-component of outgoing asymptote (optional)
24			
	F2.0	5-6	20 = Card number
	F7.6	10-16	Y-component of outgoing asymptote (optional)
25			
	F2.0	5-6	21 = Card number
	F7.6	10-16	Z-component of outgoing asymptote (optional)

<u>NOTE</u>: If the declination and right ascension of the outgoing asymptote are given, the X-, Y- and Z-components will be computed.

Deck Position	Scaling Factor	Column Number	Punch
26			
	F2.0	5-6	22 = Card number
	F9.7	10-18	Energy term (km.^{2}/sec.^{2}) (optional) (if 77777., the program will compute this value)
27			
	F2.0	5-6	23 = Card number
	F6.6	10-15	Eccentricity (optional) (program computes this if perigee distance is given)

Deck Position	Scaling Factor	Column Number	Punch
28			
	F2.0	5-6	24 = Card number
	F7.2	10-16	Semi-latus rectum (meters) (optional) (unnecessary if eccentricity > 1.0, energy term > 0 or is to be calculated)
	I2	18-19	03 = Last input record indicator
29	End of Data Card		
30	End of Job Card		
31	End of Schedule Tape Card		
32	Blank Card		

4.5.3.3 Output

The program output printout shows the input items for a case followed by the outputs. The input section contains 24 lines, one line corresponding to each of the 24 input cards. The output section contains the following quantities:

1. Components of $\bar{S}$, the outgoing asymptote (SX, SY, SZ)
2. Declination and right ascension of the outgoing asymptote (DAO, RAO)
3. Earth moon distance at encounter (RI)
4. Launcher latitude and longitude (LAT, LON)
5. Twice the total energy per unit mass, km.^{2}/sec.^{2} (C3)
6. Eccentricity and semi-latus rectum of the conic (ECC, PAR)
7. True anomaly at injection (TA)
8. Distance to perigee (RCA)
9. Inverse parking orbit rate (KPD)
10. Time of first and final burn (TLP,TFB)
11. First and final burn arcs (PLP, PFB)
12. Greenwich hour angle at encounter (GHA)
13. Lunar phase angle (LPH)

14. Longitude of the moon at encounter (LOM)
15. Distance to injection (RAD)
16. Injection velocity (km./sec.) and injection path angle (VEL, PTH)
17. Launch date - month, day, year (LAUNCH DATE)
18. Time of flight in hours (TF)
19. Arrival date - month, day, year, hours, minutes, seconds (ARRIVAL DATE)

With each launch azimuth the following quantities are printed:

1. Launch azimuth (LNCH AZMTH)
2. Launch time - hours, minutes, seconds GMT (LNCH TIME)
3. Time from launch to injection in seconds (L-I TIME)
4. Injection latitude and longitude (INJ LAT, INJ LON)
5. Range along the earth's surface (RANGE)
6. Injection right ascension and azimuth (INJ RT ASC, INJ AZMTH)
7. Injection time - hours, minutes, seconds, GMT (INJ TIME)
8. Parking orbit coast time (PO CST TIME)
9. Latitude and longitude of second stage ignition (ING 2 LAT, ING 2 LONG)

SAMPLE PRINTOUT, NEAR NEAR-EARTH AND LUNAR TRAJECTORIES PAGE 31

LNCH AZIMUTH	LNCH TIME	L-I TIME	INJ LAT	INJ LONG	RANGE	INJ RT ASC	INJ AZMTH	INJ TIME	PO CST TIME	INJ 2 LAT	INJ 2 LONG
80.00	7 42 3.0	5378.7	20.26	259.91	2102	160.81	76.94	9 11 41.7	4634.7	18.19	253.06
90.00	9 1 1.4	5111.5	19.64	241.40	3127	160.98	78.97	10 26 12.9	4347.5	17.87	234.48
100.00	10 52 28.1	4734.8	20.26	214.87	4547	160.81	76.24	12 11 22.9	3960.8	18.19	208.02
110.00	12 37 29.1	4390.2	21.74	189.44	5813	160.27	71.22	13 50 39.3	3646.2	18.93	182.83
120.00	13 57 13.9	4144.4	23.53	169.54	6673	159.33	65.17	15 6 18.3	3400.4	19.83	163.35

```
SX     0.925928 SY    -0.319736 SZ    -0.201064 DAO   -11.59921 RAO   340.94948 RI   368639.119 LAT   23.485413 LON 297.542491
C3    -1.568269 ECC    0.974058 PAR   13015.954 TA       3.2860 RCA  6593.5000 RPR   14.780225 TLP  654.00000 TFB   90.00000
PLP   24.849099 PFB    7.130000 GHA   125.5560 LPH      30.9321 LCM   243.1500 RAP    6698.85 VEL  10.91978 PTH    1.62141
LAUNCH DATE   JAN. 25.1963                              TF  69.388                    ARRIVAL DATE JAN. 27.1963  22  9 12.9
```

LNCH AZIMUTH	LNCH TIME	L-I TIME	INJ LAT	INJ LONG	RANGE	INJ RT ASC	INJ AZMTH	INJ TIME	PO CST TIME	INJ 2 LAT	INJ 2 LONG
80.00	0 46 4.1	1676.4	7.08	29.24	5333	171.38	114.07	1 14 0.5	912.4	9.98	23.03
90.00	2 31 37.4	1319.5	7.48	4.45	3960	171.55	111.93	2 43 37.4	575.5	10.13	358.12
100.00	3 56 29.7	1032.5	7.08	344.20	2863	171.38	114.07	4 13 41.7	288.5	9.98	337.99
110.00	4 49 46.0	857.4	6.11	331.07	2200	170.88	119.84	5 4 4.0	123.4	9.62	325.18
120.00	5 22 12.1	757.4	4.90	322.55	1829	170.08	126.82	5 34 49.9	23.4	9.18	317.18

```
SX     0.925928 SY    -0.319736 SZ    -0.201064 DAO   -11.59921 RAO   340.94948 RI   368639.119 LAT   23.485413 LON 297.542491
C3    -0.989860 ECC    0.983626 PAR   13079.039 TA       3.2860 RCA  6593.5030 RPR   14.780225 TLP  654.00000 TFB   90.00000
PLP   24.849099 PFB    7.130000 GHA   125.5560 LPH      30.9321 LCM   243.1500 RAP    6698.88 VEL  10.94621 PTH    1.62944
LAUNCH DATE   JAN. 25.1963                              TF  99.987                    ARRIVAL DATE JAN. 27.1963  22  9 12.9
```

4.6 SPECIAL PURPOSE AREA

This section includes special purpose programs (DUPE, MAKETAPE, TELTYP, WRTSENT, RESPLT, DUMP, RPTGEN, ICONDIS, TAPEOP, HISPRO, MESNO and TAPEGEN).

4.6.1 RESIDUAL PLOT - RESPLT

4.6.1.1 Purpose

The RESPLT program reduces observations against specified element sets and outputs the residuals on punched cards which can be used in the EAI Data Plotter.

4.6.1.2 Input - Schedule Tape Mode only (Toggle 24 On)

Deck Position	Card Type	Column Number	Punch
1	Schedule Tape Card		
2	Job Card		
3	Remarks Card		
4	Program ID Card		
		1-6	SPSJØB
		9-14	RESPLT
		17	0 = Observation cards, S-file and E-file tape inputs
			1 = Observation cards, Element Set cards and S-file tape inputs
			2 = Observation cards, Element Number cards and S-file and E-file tape inputs
			3 = Observation cards, Sensor cards and E-file tape inputs
			4 = Observation cards, Element Set cards and Sensor cards inputs
			5 = Observation cards, Element Number cards, Sensor cards, and E-file tape inputs
		18	0 = Hardcopy and punched cards output

Deck Position	Card Type	Column Number	Punch
5	Data Cards:		
	a. Input Option 0:		
	(1) Observation cards		
	b. Input Option 1:		
	(1) Observation cards		
	(2) Element Set cards		
	c. Input Option 2:		
	(1) Observation cards		
	(2) Element Number cards		
	d. Input Option 3:		
	(1) Observation cards		
	(2) Sensor cards		
	e. Input Option 4:		
	(1) Observation cards		
	(2) Element Set cards		
	(3) Sensor cards		
	f. Input Option 5:		
	(1) Observation cards		
	(2) Element Number cards		
	(3) Sensor cards		
6	End of Case Card		
7	End of Job Card		
8	End of Schedule Tape Card		
9	Blank Card		

4.6.1.3 Output

4.6.1.3.1 Printout

The printed output of RESPLT consists of reduced observations sorted by revolution number. Quantities are:

1. Satellite number
2. Observation number
3. Revolution number
4. Time (min./100) since epoch
5. Vector magnitude (km.)
6. Revolution number (N/1000) since epoch
7. Element number
8. Association status
9. Sensor number

SATNO	OBSNO	REV	DT(MIN)	VMAGN	NREV		ELNO	ASTAT	STA
034	43334	10731	-.0012	56	.007	8	119	1	039
034	43335	10731	-.0010	48	.007	8	119	1	039
034	43336	10731	-.0010	48	.007	8	119	1	039
034	43337	10731	-.0011	52	.007	8	119	1	039
034	43338	10731	-.0010	48	.007	8	119	1	039
034	43339	10731	-.0009	41	.007	8	119	1	039
034	43340	10731	-.0009	43	.007	8	119	1	039
034	43341	10731	-.0012	54	.007	8	119	1	039
034	43343	10731	-.0010	49	.007	8	119	1	039
034	43344	10731	-.0012	54	.007	8	119	1	039
034	43345	10731	-.0011	51	.007	8	119	1	039
034	43346	10731	-.0013	62	.007	8	119	1	039
034	43347	10731	-.0012	53	.007	8	119	1	039

SAMPLE PRINTOUT, RESPLT

4.6.1.3.2 Punched Cards

The punched card output of the reduction is used as input to the data plotter. The output consists of:

1. Stop card (to allow operator action)
2. Axes cards
3. Graph labeling cards (characters S, E, R, T)
4. Data (satellite number, element number, epoch revolution number, epoch time in days)

4.6.2 OTHER

The following programs in the Miscellaneous area are seldom used by the analyst. A brief description of each program is given.

4.6.2.1 DUMP

The purpose of the DUMP program is to dump the contents of core memory, in mnemonic and octal format, onto the system output tape. The DUMP program can be initiated by a console interrupt or by manually executing a jump at the computer console. In either case, the program is read in and operated by EXECMOD1.

4.6.2.2 DUPE

The DUPE program provides the means for duplicating tapes in the B-2 System. The program will duplicate a specified number of the blocks or until a sentinel block on tape is reached. The program automatically rewinds both tapes and checks the identification blocks before duplicating.

4.6.2.3 HISPRO

The purpose of the HISPRO program is to reduce the BMEWS historical data on the system output tape to a readable format.

The program will process the following types of BMEWS input messages and indicate either test or real mode:

a. Individual impacts
b. Equipment status at sites 1, 2, and 3
c. Radar status at sites 1, 2, and 3
d. Threat summary
e. Manpan Threat summary

4.6.2.4 ICONDIS

The purpose of the ICONDIS program is to produce a teletype tape of sub-satellite tracks for input to the ICONORAMA display equipment in the NORAD COC. The maximum number of satellites which can be displayed simultaneously is twelve if the updating time interval is two or four minutes, or eight if the updating time interval is one minute.

The geographical background for the display is a Mercator projection with the following limits:

78° north latitude, 69° south latitude with the east-west break of 60° east longitude. There is no overlap in longitude.

4.6.2.5 MAKETAPE

The MAKETAPE program produces, from cards, an input tape in a format acceptable to the TELTYP program. The program has an option to break up the message into 90-line segments.

4.6.2.6 MESNO

The MESNO program types on the console typewriter the current message number of the SEAIC tape and provides the operator with the option to change this number via the typewriter.

4.6.2.7 RPTGEN

The RPTGEN program produces a hard copy report in a specified format from input cards.

4.6.2.8 TAPEGEN

TAPEGEN is a utility program run under SYS (Philco 2000 operating system) control to generate binary master tapes for the B-2 System. The program has the following seven modes of operation:

a. Mode 1 - generates a new binary master from an RPL (Running Program Language) tape.

b. Mode 2 - same as Mode 1 with the added feature of allowing octal corrections to be inserted in the specified programs.

c. Mode 3 - updates the old binary master with new RPL programs.

d. Mode 4 - same as Mode 3 with the added feature of adding octal corrections.

e. Mode 5 - updates the binary master with octals only.

f. Mode 6 - updates the old binary master by deleting all program specified by the operator on the console flexowriter.

g. Mode 7 - converts a Philco 2000-211 binary master to a 212 binary master.

4.6.2.9 TAPEOP

The TAPEOP program provides the B-2 System with the following tape maintenance capabilities.

a. Write a sentinel block
b. Rewind any system tape
c. Skip a specified number of blocks or to a sentinel block
d. Copy a specified number of blocks or to a sentinel block
e. Compare two tapes for a specified number of blocks or to a sentinel block.

4.6.2.10 TELTYP

The TELTYP program is used to convert an output tape, written by other programs such as MAKETAPE, to teletype format (Baudot code). The program searches for a particular start sentinel and then converts all of the message until an end sentinel is located. It then writes all of the converted data back onto the system output tape for off-line processing.

4.6.2.11 WRTSENT

The WRTSENT program provides the means for writing sentinel blocks on tapes or rewinding tapes in the B-2 System.

4.7 1620 COMPUTER PROGRAMS

This section includes the 1620 programs used by the analyst (Jacchia, King-Hele/Findley and Launch).

4.7.1 JACCHIA II SATELLITE DECAY PREDICTION - JACCHIA

4.7.1.1 Purpose

The Jacchia program computes a predicted satellite decay revolution up to 100 revolutions after the input revolution. The computation may be performed by either or both of two methods:

4.7.1.1.1 Method A uses an equation whose solution approaches zero as the stepped revolution number in the equation approaches the decay revolution of the satellite.

4.7.1.1.2 Method B is essentially a plotting method.

4.7.1.2 Input

4.7.1.2.1 Input Mode A (legal only using Method A)

Deck Position	Card Type	Column Number	Punch
1	Satellite Number Card		
		1-10	Satellite number (right adjust)
2	Data Card		
		1-10	x.xxxxxxxx (days) = Period
		11-20	xxxxxxxx.x = Revolution number
3	Data Card 2:	same as Data Card 1	
4.	Data Card 3:	same as Data Card 2	

NOTE: Data cards must be in ascending order by revolution number.

4.7.1.2.2 Input Mode B

Mode B uses one Satellite Number card (see Mode A format) and from 6 to 100 Data Cards (see Mode A format). Data Cards must be in ascending order by revolution number.

4.7.1.2.3 Input Mode C

Mode C requires from 6 to 100 seven-card element sets. The element sets must be in ascending order by element set number.

4.7.1.3 Toggle Switch Settings

Switch	Position	Input	Method
1	On	A only	A only
1	Off: Program tests switch 2		
2	On	B	B
2	Off	C	B
3	On	see SW 2	A in addition to B
3	Off: No effect		
4	On: Input data not printed on typewriter		
4	Off: Input data printed on typewriter		

4.8.1.4 Output

The printed output consists of the following information:

1. Satellite number
2. Number of input points (Method B)
3. Period in days and revolution number (input data)
4. Decay revolution

SAMPLE PRINTOUT, JACCHIA II

```
                              Satellite number
                              Pi
   713            11          number of points
.06293789          7.0        Rev i
.06290442         28.0
.06280657         85.0
.06264376        191.0
.06257386        235.0
.06240596        300.0                  Method B
.06240441        314.0
.06220669        393.0
.06202944        455.0
.06177842        512.0
.06164303        535.0
DECAY ON THIS REV -        591.0
.06293789          7.0
.06257386        235.0                  Method A, points
.06164303        535.0                  selected by the program
DECAY ON THIS REV -        601.0
```

4.7.2 KING-HELE/FINDLEY DECAY PREDICTION

4.7.2.1 Purpose

The King-Hele and Findley programs both compute a predicted satellite decay day using the same input but different formulas. The two programs are run together.

4.7.2.2 Input

One seven-card element set is the only input required.

4.7.2.3 Output

The printout consists of the following quantities:

1. Satellite number
2. Element set number
3. Predicted day of decay from January 1, and day and year if before 3 years. The output contains both King-Hele and Findley methods.

SAMPLE PRINTOUT, KING/HELE FINDLEY

DECAY PREDICTIONS

		DAYS FROM JAN 1		DAY AND YEAR, IF BEFORE 3 YEARS	
SAT	EL	KING HELE	FINDLEY	KING HELE	FINDLEY
713	11	29	25	29 1964	25 1964

4.7.3 1620 LAUNCH

4.7.3.1 Purpose

The 1620 Launch program computes a set of nominal elements given nominal input data.

4.7.3.2 Input

Deck Position	Card Type	Column Number	Punch
1	Parameter Card 1		
		1-3	Satellite number
		4-6	Element Set number
		9-20	Satellite name
		40-50	Eccentricity
		51-64	Inclination
2	Parameter Card 2		
		1-9	Day of launch
		10	0 = Launch direction south
			1 = Launch direction north
		11-24	Anomalistic period
		25-36	Time (sec.) from lift-off to injection
		37-50	Latitude of injection (+ is north and - is south)
		51-64	Longitude of injection (+ is west and - is east)
		65-78	Perigee (in earth radii)

4.7.3.3 Output

The printout of the program is the same as the punched card output, that is, a standard 7-card element set. L_o, C_a, and C_n are omitted. Specifically the quantities printed are:

1. Satellite number.
2. Element set number.
3. Satellite name.
4. Epoch revolution (o).
5. Eccentricity, e.
6. Inclination, i.
7. Epoch year (always current year).
8. Epoch time, T_o.
9. Anomalistic period, P_a (days/rev).
10. Right ascension of node, Ω (deg.).
11. Argument of perigee ω (deg.).
12. Perigee distance (earth radii).
13. Change in right ascension, $\dot{\Omega}$ (deg./day).
14. Change in argument of perigee, $\dot{\omega}$ (deg./day).
15. Semi-major axis, a (earth radii).
16. Nodal period, P_n (days/rev).
17. Bulletin expiration time, always current year, first month, first day.
18. Element card numbers.

SAMPLE PRINTOUT
1620 LAUNCH

```
 ┌──Satellite no.
 │   ┌──Element set no.
 │   │  ┌──Card No.
 │   │  │   ┌──Satellite name
 │   │  │   │  ┌──Epoch Year
 │   │  │   │  │               (Epoch rev)   (e)        (i)
S01  0  1  SAMPLE 1                  x.      0.0155     70.0                E
               │           (to)
S01  0  2  1964          41.97791                                           E
            (Pa)           (Ω)           (ω)          (q)
S01  0  3  .06265722     214.67115     155.14981    1.02847401              E
                           (Ω̇)           (ω̇)
S01  0  4                -2.92204      -1.77324                             E

S01  0  5                                                                   E
          (a)               (Pn)
S01  0  6  1.044662        .06266655                                        E
                               (BLTN Date)
S01  0  7                        2040101                                    E
```

4.8 STANDARD SYSTEM INFORMATION

This section includes the following standard items of system information:

a. OCS Sequences

b. Schedule Tape Operation - card and tape requirements

c. Observation Card

d. Satellite Number Card

e. Sensor File Card

f. Element Set File Cards

g. Acquisition File Card

h. Information File Cards

i. Communication File Cards

j. SEAI File Deletion Card

4.8.1 OCS Sequence

4.8.1.1 Group 1: Must also have accompanying indication as to source of observation input.

OCS Number:	ØCS1**	ØCS2	ØCS3	ØCS4	ØCS5	ØCS6
Toggle Control:		2-Up	3-Up	4-Up	5-Up	6-Up
Programs:		ORCON	ORCON	ORCON	ORCON	ORCON
		RASSN	RASSN	RASSN	RASSN	
		SGPDC	SGPDC	SGPDC		
		BLTNSGP	BLTNSGP			
		GLASGP				

4.8.1.2 Group 2: R Tape must be mounted prior to initiation of sequence.

OCS Number:	ØCS7	ØCS8	ØCS9	ØCS10	ØCS11**
Toggle Control:	7-Up	8-Up	9-Up	10-Up	
Programs:	RASSN	RASSN	RASSN	RASSN	
		SGPDC	SGPDC	SGPDC	
			BLTNSGP	BLTNSGP	
				GLASGP	

4.8.1.3 Group 3: After initiation, Executive program will request a table of satellite numbers (SATTB) to be entered.

OCS Number:	ØCS12	ØCS13	ØCS14	ØCS15**	ØCS16	ØCS17
Toggle Control:	12-Up	13-Up	14-Up		16-Up	17-Up
Programs:	SGPDC	SGPDC	SGPDC		BLTNSGP	BLTNSGP
		BLTNSGP	BLTNSGP			GLASGP
			GLASGP			

OCS Number:	ØCS18**	ØCS19	ØCS20**	ØCS21**
Toggle Control:		18-Up		
Programs:	GLASGP			

**currently not used.

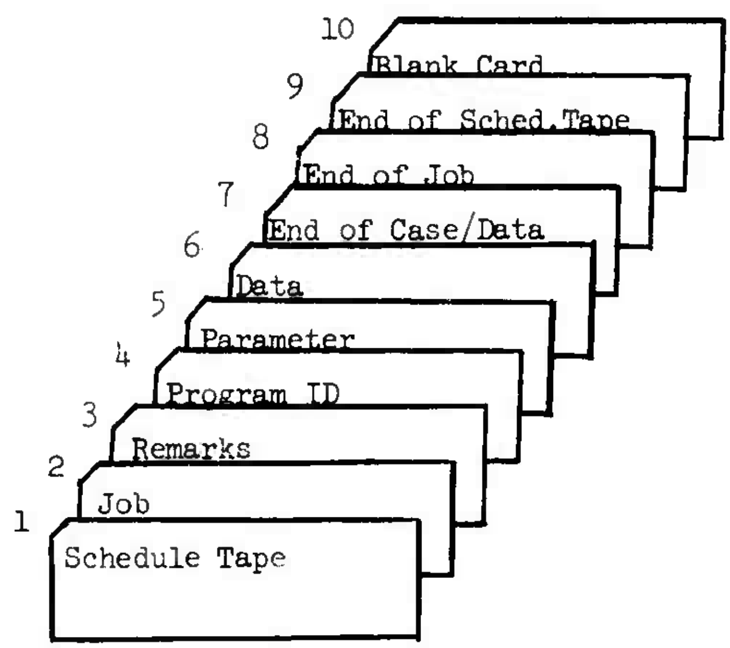
4.8.2 Schedule Tape Operation

4.8.2.1 Standard Card Formats

Card Type	Column Number	Punch
Schedule Tape Card		
	1-8	70 SCHTP
	9	11, 8 and 2 = * = end of block
	80	J = card type
Job Card		
	17-19	JØB
	25	1 = first schedule tape program run
		2 = second schedule tape program run
		etc.
Remarks Card (optional)		
	17-19	REM
Program I.D. Card (see program)		
Parameter Card (see program)		
Data Cards (see program)		
End of Case Card (optional)		
	1-8	END CASE
	9	11, 8 and 2 = * = end of block
	80	J = card type
End of Data Card (optional)		
	17-23	ENDDATA
End of Job		
	1-8	ENDØFJØB

Card Type	Column Number	Punch
	9	11, 8 and 2 = * = end of block
	80	J = card type
End of Schedule Tape		
	1-8	ENDSCHED
	9	11, 8 and 2 = * = end of block
	80	J = card type
Blank card		

4.8.2.2 Deck Format



4.8.2.3 Input Tape Requirements

See Figure 4-1

Program	Logical Tape Unit ID												
ID	0	1	2	3	4	5	6	7	8	9	10	11	12
BLTNSGP		X	X		X							X	
BNSCHED		X	X		X							X	
ESPOD													
GLASGP		X	X		X							X	
GRNTRK	Input	X										X	
HELIO	Input	X			X			EPHEMERIS (XYZLA)			EPHEMERIS		
IOANGLE	70 SCRA	X	X		X							X	
IOHG		X	X		X							X	
IORF		X	X		X							X	
LAP	Blank	X			X							X	
LOCVEC	Input	X	X		X							X	
MUNENDC	Input	X		EPHEMERIS		SCRATCH	SCRATCH				SCRATCH	X	
NEARBBA	Input										EPHEMERIS	X	
OBSERVE	FANCARDS	X	X		X			70 SCRA	70 SCRA	70 SRADUN		X	
OBSSEP		X				70R TAPE		70 SCRA (Hi-pri)	70 SCRA (Lo-pri)				
PSR		X	X		X			70 SCRA				X	
RASSN		X		70 SEAI1 (SRCHEK)	X	70R TAPE	70 SRADU (SRTMRG)		70 SCRA	70 SRADUN		X	
REDUCT	Input	X	X		X			STELTAPE	SCRATCH			X	
RESPLT		X	X		X							X	
ROC	Input	X	X		X				70 SCRA			X	
SEAI	Input	X		SCRATCH/ old 70 SEAI1	X new							X	
SGPDC		X		70 SEAI1 (backup)	X		70 SRADU		70 SCRA			X	
SPIRDECB													
SPWDC		X	X		X		70 SRADU	70 WEIGHT				X	r
SYSBULL	Input	X	X		X				70 SCRA			X	
XROADS		X	X		X							X	
XYZLA	Input	X			X			Blank/ EPHEMERIS	Blank			X	

<u>NOTE:</u> Tape #1 = 70BINMST, Tape #2 = 70 SCHTP, Tape #4 = 70 SEAI1, Tape #11 = 7ØOUTPUT

Figure 4-1
Initial Tape Setup

4.8.3 Observation Card Format

Card Type	Column Number	Punch
Observation Card		
	1-3	Satellite number. Column 1 contains a minus sign if this is a classified observation; $\underset{0}{+}$ or $\underset{0}{-}$ are not allowed
	4-5	Equipment Type
	6-9	Sensor Number
	10	Accuracy or Signal Strength
	11-15	Date
	16-24	Time (Z)
	25-30	Elevation/declination. Column 25 can be overpunched + or -.
	31-37	Azimuth/right ascension. Column 31 can be overpunched + or -.*
	38-44	Slant range (km.)
	45-53	Range rate (km./sec.) with implied decimal point between columns 46 and 47; or Maximum frequency shift (cycles/sec.^{2}) with implied decimal point between columns 52 and 53.

* A minus overpunch in col. 31 indicates cols. 25-30 and 31-37 are declination and right ascension respectively.

Card Type	Column Number	Punch
	54	0, Blank = Range rate in cols. 45-53 1 = Maximum frequency shift in cols. 45-53.
	55-57	Brightness at observation time (see paragraph 4.8.3.2)
	58-59	Maximum brightness
	60-61	Minimum brightness
	62-63	Time interval of brightness
	64-65	Date or line number
	66-69	Message number
	70	Equinox (see paragraph 4.8.3.3)
	73-78	Observation number (assigned by ØRCØN)
	79	Switch indicator used by manual system
	80	Card type (code type = Any numeric between 0 - 9) identifies an Observation Card. 0 = Unknown, 1 - 9 coded according to the Association Status as determined in RASSN.

4.8.3.1 Column 10: Accuracy

Either accuracy or signal strength may be indicated in column 10.

If entry in columns 4 and 5 is 31 or greater, column 10 contains signal strength. If entry is 30 or less, column 10 contains accuracy.

Code Figure	Accuracy	Signal Strength
0	Normal observations made under fair conditions.	Signal strength good, reliable measurement.
1	Observations slightly under par due to outside interference (e.g. some clouds, reduced visibility).	Signal fair.
2	Observations only poor due to outside interference.	Signal weak, results poor.
3	Only estimates possible (malfunction of instrument. Too short time of object seeing).	Signal questionable.
4	Doubtful observations, unable to verify either object or instrument behavior. Observations should be considered only as tentative.	

4.8.3.2 Columns 55-63 Cross Section, Frequency - for manual runs only

The block containing columns 55 through 63 is a dual purpose block where cross section and frequency, or magnitude and time interval are indicated. In order to specify cross section and frequency, a minus is used in column 58. No sign is used in column 58 when this block contains magnitude and time interval.

Cross section, given in square meters, is listed in columns 55 through 57. To indicate less than one square meter cross section, use appropriate numbers and a minus in column 55, thus in effect, putting a decimal point before column 55. For larger values where three digits would not be sufficient, use a plus in column 55 to represent ten times the indicated value (adding a zero to the value listed).

Frequency in megacycles, is listed in columns 58 through 63 with the decimal point understood to be located between columns 60 and 61. In rare cases it might be desirable to increase the range of frequency given either side of the decimal point. To do this, use a minus in column 63 to move the point one place to the left, or a plus in column 63 to move the point one place to the right.

4.8.3.3 Column 70. Equinox

Column 70 contains year of Equinox as specified by the following:

0 = year of date
1 = 1900
2 = 1925
3 = 1950
4 = 1975
5 = 2000
6 = 1850
7 = 1855
8 = 1875
9 = to list actual year, if not provided above, list last two digits of year in columns 71 and 72 and use a minus in column 70 for 18 and a plus in column 70 for 19. Example: Equinox of 1961 would contain "+61" in columns 70, 71, and 72.

4.8.4 Satellite Number Card Format

Card Type	Column Number	Punch
Satellite Number Card		
	1-8	Satellite Number (rt. adj.)

NOTE: Cols. 1-8 may be repeated, once for each satellite, up through col. 72.

	80	R = Card type

4.8.5 Sensor File Card Format

Card Type	Column Number	Punch
Sensor File Card		
	1-4	Sensor Number
	5-11	ϕ° (+N) = latitude (decimal assumed between cols. 7-8)
	12-19	λ° (+W) = longitude (decimal assumed between cols. 15-16)
	20-25	H (meters) = altitude (decimal assumed after col. 25)
	33	Classification (U, C, S)
	37-54	Location (descriptive)
	60-78	Remarks
	79	* = this sensor is in S-file
	80	S = Card type

4.8.6 Element Set File Card Formats

4.8.6.1 Seven-Card Element Set

Card Type	Column Number	Punch
Element Card 1		
	1-3	Satellite number (rt. adj.)
	4-6	Element set number (rt. adj.)
	8	1 = Card number
	9-18	Satellite name for Element File Update
	23-36	N_o = Epoch revolution
	37-50	e = Eccentricity
	51-64	i = Inclination (degrees)
	80	Card type (Code type = E, F, G, or H):
		E = Nodal Elements
		F = Nodal Elements from Lockheed
		G = Nodal Elements from NASA
		H = Nodal Elements from N M
Element Card 2		
	1-3	Satellite Number (rt. adj.)
	4-6	Element set number
	8	2 = Card number
	9-12	Year of T_o
	23-36	T_o = Time of Epoch (day and fraction of days in year)
	80	Card Type (Code type = E, F, G, or H):
		E = Nodal Elements
		F = Nodal Elements from Lockheed
		G = Nodal Elements from NASA
		H = Nodal Elements from N M

Card Type	Column Number	Punch
Element Card 3		
	1-3	Satellite number (rt. adj.)
	4-6	Element set number (rt. adj.)
	8	3 = Card number
	9 -22	P_A = Anomalistic Period at Epoch (days/rev.)
	23-36	Ω_o - Right Ascension of ascending node (deg.)
	37-50	ω_o - Argument of Perigee (deg.)
	51-64	Q_o - Perigee (earth radii)
	80	Card type (Code type = E, F, G, or H): E = Nodal Elements F = Nodal Elements from Lockheed G = Nodal Elements from NASA H = Nodal Elements from N M
Element Card 4		
	1-3	Satellite number (rt. adj.)
	4-6	Element set number (rt. adj.)
	8	4 = Card number
	9-22	C = Rate of change of period in days/(rev.)^2
	23-36	$\dot{\Omega}_o$ = Time derivative of Right Ascension of ascending node (deg./day)
	37-50	$\dot{\omega}_o$ = Time derivative of Argument of Perigee (deg./day)
	80	Card type (Code type = E, F, G, or H): E = Nodal Elements F = Nodal Elements from Lockheed G = Nodal Elements from NASA H = Nodal Elements from N M

Card Type	Column Number	Punch
Element Card 5		
	1-3	Satellite number (rt. adj.)
	4-6	Element set number (rt. adj.)
	8	5 = Card number
	80	Card type (Code type = E, F, G, or H):
		E = Nodal Elements
		F = Nodal Elements from Lockheed
		G = Nodal Elements from NASA
		H = Nodal Elements from N M
Element Card 6		
	1-3	Satellite number (rt. adj.)
	4-6	Element set number (rt. adj.)
	8	6 = Card number
	9-22	a = Semi-major axis (earth radii)
	23-36	P_N = Nodal period (days/rev.)
	37-50	C_N = Rate of change of nodal period in days/(rev.)^2
	51-64	C_p = Phase angle coefficient (optional)
	80	Card type (Code type = E, F, G, or H):
		E = Nodal Elements
		F = Nodal Elements from Lockheed
		G = Nodal Elements from NASA
		H = Nodal Elements from N M
Element Card 7		
	1-3	Satellite number (rt. adj.)
	4-6	Element set number (rt. adj.)
	8	7 = Card number
	23-29	Initial Revolution, decimal may be punched in column 29

Card Type	Column Number	Punch
7 (Cont'd)	30-36	Final Revolution, decimal may be punched in column 36
	37-50	YMMDDHHMMSS.SS = Expiration date of Bulletin
	51-58	XXXXX.XX = RMS
	59-66	Number of observations used in obtaining RMS
	67	Blank or 0 = Correct all elements
		1 = Do not correct the inclincation
		2 = Do not correct the drag term
		3 = Do not correct inclination or drag term
		4 = Correct time equation only
		8 = Do not rerun if drag term becomes positive
		9 = Do not correct the inclination or rerun if drag term becomes positive
		+ = New epoch is time of last acceptable residual. Initial revolution of the new bulletin is the revolution which the satellite is on at the time of program run. New bulletin time = operational time of old bulletin, which stops at time of program run.
		- = New epoch is time of last acceptable residual. Initial revolution of new bulletin is the final rev.

Card Type	Column Number	Punch
		minus 1 of old bulletin. New bulletin time = 4/3 old bulletin.
		E = Used only when elements are good but bulletin is expiring or epoch is greater than 100 days.

NOTE: +, -, or E used only for OCS runs.

4.8 6.2 Four-Card Element Set

Card Type	Column Number	Punch	
Element Card 0			
	1	0 = Card number	
	3	Blank = SPADATS number	
		4-9 = SPASUR number used prior to SPADATS number	
	4-6	Satellite number	
	8	Blank = SPADATS elements	
		9 = SPASUR elements	
	9-11	Element Set number	
	13-14	Last two digits of year	
	16-24	Greek letter designator	
	26-28	Piece number	
	30-31	US = United States	Country of Origin
		SR = Russia	
		FR = France	
		UK = England	
		CA = Canada	
		JA = Japan	
	32	0 = Unknown	Functional Type
		1 = Scientific	
		2 = Weather	
		3 = Navigation	
		4 = Communications	
		5 = Manned	

Card Type	Column Number	Punch
	33	0 = Silent
		1 = Transmitting
		2 = Rocket body silent
		3 = Rocket body transmitting
		4 = Metal or other fragment
		9 = Unclassified elements of all foreign launched vehicles
	35-36	Last two digits of epoch year
	38-39	Month of epoch
	41-42	Day of epoch
	44-46	Bulletin number
	48-49	Month of bulletin issue
	51-52	Day of bulletin issue
	54-56	Number of revolutions covered by bulletin
Element Card 1		
	1	1 = Card number
	2-12	Same as cols. 2-12, Card number 0
	13-26	xxxxx.xxxxxxxx = Modified Julian Day of epoch
	28-38	xx.xxxxxxxxx (e.r.) = a, semi-major axis
	40-50	$\pm$.xxxxxx$\pm$xx (e.r./day) = da/dt, the first time derivative of a

Card Type	Column Number	Punch
	52-62	$\pm$.xxxxxx$\pm$xx (e.r./day/day) = d^2a/dt^2, the second time derivative of a
	64-66	Check Sum - the arithmetic sum of digits in each line, plus one for each minus sign
Element Card 2		
	1	2 = Card number
	2-12	Same as cols. 2-12, Card number 0
	13-20	xxx.xxxx$^{\circ}$ = Inclination
	22-29	xxx.xxxx$^{\circ}$ = Argument of Perigee
	31-38	xxx.xxxx$^{\circ}$ = Right Ascension of the ascending node
	40-47	.xxxxxxx = Eccentricity
	49-55	xxxx.xx (min.) = Anomalistic Period
	57-62	xxxxxx (km.) = Height of Perigee above Earth's Equatorial Radius
	64-66	Check Sum
Element Card 3		
	1	3 = Card number
	2-12	Same as cols. 2-12, Card number 0
	13-20	xxx.xxxx$^{\circ}$ = Mean longitude
	22-29	$\pm$xx.xxxx$^{\circ}$ (deg./day) = $d\omega/dt$, first time derivative of the Argument of Perigee

Card Type	Column Number	Punch
3 (Cont'd)	31-38	$\pm$xx.xxxx (deg./day) = $d\Omega/dt$, first time derivative of the Right Ascension of the ascending node
	40-47	+.xxx$\pm$xx (per day) = de/dt, first time derivative of eccentricity
	49-55	$\pm$.xxxxx (min./day) = dP_a/dt, first time derivative of the Anomalistic Period
	57-62	Revolutions from launch
	64-66	Check sum

4.8.6.3 N M Element Set

Card Type	Column Number	Punch
Element Card 1		
	1-12	t_o = Initial time point of integration (min.), (floating point)
	13-24	Δt = Integration time step interval (min.), (floating point)
	25-36	t_f = Final time point to be integrated (min.), (floating point)
	37-48	d = The caliber or reference diameter of the vehicle (meters), (floating point)
	49-60	m = The weight of the vehicle (kilograms), (floating point)
	79	1 = Card number (not used in manual programs)
	80	Card type (not used in manual programs)

NOTE: Floating point numbers are given in the format: $\underline{+}$.xxxxxxx$\underline{+}$xx

Card Type	Column Number	Punch
Element Card 2		
	1-12	L_o = mean longitude at initial time (radians), (floating point)
	13-24	a_{xN}, (floating point)
	25-36	a_{yN}, (floating point)
	37-48	h_x = x-component of angular momentum, (floating point)
	49-60	h_y = y-component of angular momentum, (floating point)

Card Type	Column Number	Punch
2 (Cont'd)	61-72	h_z = z-component of angular momentum, (floating point)
	79	2 = Card number (not used in manual programs)
	80	Card type (not used in manual programs)

NOTE: Floating point numbers are given in the format: $\pm$.xxxxxxx$\pm$xx

4.8.7 Acquisition File Card Format

Card Type	Column Number	Punch
Acquisition File Card		
	1-3	Satellite number (rt. adj.)
	5-7	Element set number (rt. adj.)
	15-18	Sensor number (rt. adj.)
	20-24	Initial revolution = first revolution for which Look Angles are computed
	26-30	Final revolution = last revolution for which Look Angles are computed
	32-34	Grid size = interval between successive Look Angles (min.)
	36	1 = Look Angles are desired for visual passes 0 = Look Angles are desired for all passes, whether visual or not
	37	0 = Short output format 1 = Long output format (includes sun's elevation and illumination)
	38-42	Maximum range that the sensor can read (km.)
	43-45	Minimum elevation that the sensor can read (deg.)
	46-48	Maximum elevation that the sensor can read (deg.)

Card Type	Column Number	Punch
	49-51	Minimum azimuth that the sensor can read (deg.)
	52-54	Maximum azimuth that the sensor can read (deg.)
	55	0 = Generate all-points look angles (rise to set)
		3 = Generate CPA (i.e., generate first, last, and point of closest approach) look angles
		4 = Generate BAKER-NUNN look angles
		6 = Generate all points-scheduling (i.e., write Look Angles on Schedule Type)
		9 = Generate CPA-scheduling
	56	1 = Hardcopy and TTY output
		0 = TTY outputs
	57	C-type Output Coordinates (see Figure 4-
	80	A = Card type

4.8.8 Information File Card Format

Card Type	Column Number	Punch
Information Card 1		
	1	0 = Geocentric elements in cols. 51-55
		1 = Cols. 51-55 blank
		2 = Heliocentric elements in cols. 51-55
		3 = Barycentric elements in cols. 51-55
	5	Classification (U, C, S)
	6-8	Satellite Number (rt. adj.)
	9-10	Last two digits of year of launch
	11-12	Greek letter-number designator: 01 = α, etc.
	14	Component no. A-Z
	17-24	Satellite name - alphanumeric
	25-40	Common name
	41-42	Launch day
	43-45	Launch month
	47-48	Launch year (last 2 digits)
	49-72	Launch site
	75-77	SPADATS number
	78-79	01 = Card number
	80	I = Card type
Information Card 2		
	1-8	Booster country
	9-16	Payload country
	17-32	Mission or Description
	33-40	Weight (kg.)

Card Type	Column Number	Punch
	41-48	Shape
	49-56	Length (meters)
	57-64	Height (meters)
	65-72	Width (meters)
	75-77	Satellite number (rt. adj.)
	78-79	02 = Card number
	80	I = Card type
Information Card 3		
	1-8	Diameter (meters)
	25-32	M^2 = Radar Cross Section
	41-56	Type Transmission
	57-61	Tumbling date
	62-64	Tumbling rate (rev/min)
	75-77	Satellite number (rt. adj.)
	78-79	03 = Card number
	80	I = Card type
Information Card 4		
	1-16	Stabilization
	17-24	Maneuver characteristics
	25-32	xxxxx.xx = Transmitting frequency

NOTE: Cols. 25-32 may be repeated, once for each frequency, up through col. 64.

	75-77	Satellite number (rt. adj.)
	78-79	04 = Card number
	80	I = Card type

Card Type	Column Number	Punch	
Information Card 5			
	1-8	Anomalistic Period (days)	
	9-16	Inclination	
	17-24	Apogee	
	25-32	Perigee	
	33-40	Eccentricity	
	75-77	Satellite number (rt. adj.)	
	78-79	05 = Card number	
	80	I = Card type	
Information Card 6			
	21	Classification	
	25-26	Country code (US, SR, JA, UK, CA)	
	31-32	Box score code	
		U. S. EARTH PAYLOAD	00
		U. S. EARTH DEBRIS	01
		U. S. SPACE PAYLOAD	02
		U. S. SPACE DEBRIS	03
		USSR EARTH PAYLOAD	04
		USSR EARTH DEBRIS	05
		USSR SPACE PAYLOAD	06
		USSR SPACE DEBRIS	07
		U. K. EARTH PAYLOAD	08
		U. K. EARTH DEBRIS	09
		U. K. SPACE PAYLOAD	10
		U. K. SPACE DEBRIS	11
		OTHER EARTH PAYLOAD	12
		OTHER EARTH DEBRIS	13
		OTHER SPACE PAYLOAD	14
		OTHER SPACE DEBRIS	15

Card Type	Column Number	Punch
	75-77	Satellite number (rt. adj.)
	78-79	06 = Card number
	80	I = Card type
Information Card 7		
	25-72	Address codes (zero prior to 3 letter/ number codes) e.g. OSCA, 0659
	75-77	Satellite number (rt. adj.)
	78-79	07 = Card number
	80	I = Card type

4.8.9 Communication File Card Format

Card Type	Column Number	Punch
Communication Card 1		
	1-4	Sensor number (rt. adj.)
	5	1 = Second card follows
		0, Blank = No second card
	6	0 - Unclassified
		1 - Unclassified/EFTO
		2 - Confidential
		3 - Confidential/Noforn
		4 - Secret
		5 - Secret/Noforn
	7	R - Routine
		P - Priority
		O - Immediate
		Z - Flash
	8	A - Aircomnet
		R - 1 Aero
		S - SSO
	9-15	Unclassified routing indicator (lft. adj.)
	16	"From" line indicator:
		0 = NORAD SPADATS
		1 = 1 Aero
		5 = SSO CONAD
	17-64	"To" line
	73-79	Classified routing indicator (lft. adj.)
	80	C = Card type

Card Type	Column Number	Punch
Communication Card 3 (for information and pass lines only)		
	1-40	Information line, including routing indicator (lft. adj.)
	41-72	Pass line
	80	C = Card type

4.8.10 SEAI File Deletion Card Format

Card Type	Column Number	Punch
SEAI File Deletion Card		
	1	D = Card type
	2-5	Satellite Number (rt. adj.)
	6-8	Sensor Number
	80	Card type (S, E, A, or I)

Section 5

APPENDICES

The following information is included in the Appendices section:

a. Forms

b. Miscellaneous - constants, conversion factors, charts, etc.

c. Observation formats.

d. Glossary

5.1 FORMS

The following 1st Aerospace Squadron forms are used by the analyst:

a. Analyst Launch Checklist (Page 5-5)

b. Bulletin Input Data (Page 5-6)

c. Data Request and Routing Sheet (Page 5-7)

d. Least Squares Points (Page 5-8)

e. Look Angle Request (Page 5-9)

f. Satellite Observation Conversion Sheet (Page 5-10)

ANALYST LAUNCH CHECKLIST

PRE-LAUNCH: Program/FTV:	Nominal No:	PMR No:
Launch Site:	No. Pieces Expected:	
Transmitting Frequencies:		
Size and Weight:		

NOMINAL DATA

Injection: Latitude:	Longitude:	Time(L/O+Sec)

ELEMENTS

N_o	T_o	$P_{n(days)}$
i	$P_{n(min)}$	$\dot{\omega}$
c	$\dot{RA}$	A
RA	ω	
q	e	

POST LAUNCH

Launch Time:	Obj No:	Int'l Desig:

SENSOR LOOK ANGLE SCHEDULE

REV	315	316	328	329	330	336	337	339	340	345	NAV	Other

Remarks:

1ACS Form 31, Mar 64

BULLETIN INPUT DATA *(Right Adjust All Fields)*	ORIGINATOR		DATE

FIELD	DESCRIPTION	COLUMN	
1	SATELLITE NUMBER	1-3	
2	ELEMENTS NUMBER (give only if non-current)	4-6	
3	LEAST SQUARES DRDER DF EQUATION	7	
4	LEAST SQUARES: NUMBER OF POINTS (see following sheet)	8-9	
5	LEAST SQUARES: IN, PUNCH "D" RAH, PUNCH "1"	10	
6	UPDATEO ELEMENTS NUMBER	11-13	
7	UPDATE TD REVDLUTIDN NUMBER	14-18	
8	PERIGEE IN EARTH RADII (give only if q F a. (1-e.)	19-25	
9	TEST BULLETIN STARTING AT REVDLUTION NUMBER	26-30	
10	TEST BULLETIN ENOING AT REVOLUTION NUMBER	31-35	
11	IF DESIRE BULLETIN, PART 1 LIST ELEMENTS, PUNCH "1". IF OESIRE REFER TD PREVIDUS BULLETIN, PUNCH "0".	36	
12	BULLETIN NUMBER	37-39	
13	BULLETIN FROM REVDLUTIDN NUMBER	40-44	
14	BULLETIN TD REVOLUTION NUMBER. ND: PUNCH "0"	45-49	
15	GRID: STANDARO: PUNCH "1" SPECIAL: PUNCH "2" (see Items 17-20 below)	50	
16	GRID AT REVOLUTION NUMBER	51-55	
17	SPECIAL GRID: LDWEP LATITUDE (generally 0) (only if "2" punch for item 15)	56-57	
18	SPECIAL GRID: UPPER LATITUOE	58-59	
19	SPECIAL GRID: INCREMENT	60-61	
20	SPECIAL GRIO: SINGLE LATITUDE	62-65	
21	YEAR (last 2 digits)	66-67	
22	PRINT ONLY, PUNCH "0" PUNCH (for transmission), PUNCH "1".	68	
23	CLASSIFIEO, PUNCH "1" UNCLASSIFIEO, PUNCH "0"	69	
24	DRIGINATOR'S NUMBER	70-75	
25	DAY OF YEAR	76-80	

1st AEROSPACE SQ ADC FORM 5

DATA REQUEST AND ROUTING SHEET

SECURITY CLASSIFICATION	INPUT	OUTPUT
	☐ UNCLASS ☐ SECRET	☐ UNCLASS ☐ SECRET

DATE	JOB NUMBER	PRIORITY	DELIVER INPUT TO ORIG		
					ELEMENTS
					OBSERVATIONS

SATELLITE AND ELEMENT NUMBER	ROUTING INSTRUCTIONS						
	ROUTING	TIME	OUTPUT	COPIES	DELIVER TO		OTHER
	DISPATCHER		PRINTOUT			ORIG	
	DATA CONVERSION		CARDS			ORIG	
	COMPUTER		PAPER TAPE AND PRINTOUT			ORIG	
	DD						

ORIGINATOR

	ANALYST		DSSO		PROGRAMMER		DISPATCHER		DATA

OTHER AGENCIES	TELEPHONE NUMBER	SIGNATURE

JOB TYPES		REMARKS
OCS NUMBER		
REDUCTIONS		
OC		
SEAIC UPDATE		
SUM		
BULLETINS		
GLAP		
FAN		
PREP		
PRINT PUNCH		
LISTINGS		
COMPILE		
TEST RUN		
USE CODE		

IACS ADC FORM 11
FEB 63

	LEAST SQUARES POINTS																				
COLS	1	2	3	4	5	6	7	8	9	10		11	12	13	14	15	16	17	18	19	20
				.													.				
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± Δt_n or ΔRA_n

± ΔN

LOOK ANGLE REQUEST

ORIGINATOR

DATE

Right Adjust All Numerical Data

SAT NR	ELEM NR	N_o	STN NR	INITIAL REV NR	FINAL REV NR	Δt	PASSCODE	FORMAT	(KM) MAX RANGE	(Deg) MIN ELEV	(Deg) MAX ELEV	(Deg) MIN AZ	(Deg) MAX AZ	TYPE	TTY	C-TYPE		STATION NAME	A
1 3	5 7	9 13	15 18	20 24	26 30	32 34	36	37	38 42	43 45	46 48	49 51	52 54	55	56	57	58 72	73 79	80
																			A
																			A
																			A
																			A
																			A
																			A
																			A
																			A
																			A
																			A

[illegible] - Insert (-10) if Col 55 is indicated with a (5) [illegible]LAP only. Otherwise use elements number.

[illegible] - Leave Station Nr Blank.

[illegible] - [illegible] SAT NR, ELEM NR [illegible] and [illegible] REV NR

[illegible] - Enter initial and final day [illegible] fields for INITIAL and [illegible] REV. Nr punch (DDD.F); [illegible] point must appear in field.

Col 32 - 34 - Punch decimal point in Δt field when Δt not in whole numbers.

Col 36 - Pass Code
- 0 = All passes (A)
- 1 = Visual passes (V)

Col 37 - Format
- 0 = Short Format (S)
- 1 = Complete Format (C)

Col 55 - Type
- 0 = All point GLAP/GLASGP
- 1 = One point GLAP
- 2 = FLAP
- 3 = 3 point GLAP/GLASGP
- 4 = BLAP
- 5 = Alert Deck follows (GLAP)
- 6 = All point GLAP with stn sched (ALL SCHED)
- 7 = One point GLAP with stn sched (1 SCHED)
- 8 = SLAP (SYS ONLY)
- 9 = 3 point GLAP with stn sched (3 SCHED)

Col 56 - TTY tape (GLASGP only)
- 0 = Yes
- 1 = No

Col 57 - C-Type (GLASGP only)
- 1 = EL, AZ
- 2 = EL, AZ, RNG
- 3 = EL, AZ, RNG, RGRATE
- 4 = EL, AZ, RNG, RGRATE, RA, DEC
- 5 = RA, DEC
- 6 = RA, DEC, RNG
- 7 = CHA, DEC
- 8 = LHA, DEC, RNG
- 9 = RA, DEC, RNG, RGRATE
- 0 = RGRATE

SATELLITE OBSERVATION CONVERSION SHEET

SATELLITE NAME	SATELLITE NUMBER	DESIGNATOR	MONTH	YEAR

SAT NR	TYPE	STATION NUMBER	ACC	DATE Y M M D D	TIME (Z) H H M M S S .S S S	(1) ELEVATION D D.D D D D / (2) DECLINATION D D.D D D D	AZIMUTH D D D.D D D D / (-) RIGHT ASCENSION H H M M S S.S	SLANT RANGE (KM) N N N N N.K K	(1) RANGE RATE KM/SEC N K.K K K K K K N / MAX FREQ SHIFT C/SEC C C C C C C C C.C	D or 1	MAGNITUDE: AT ORB TIME X X.X / MAX X X / MIN X X / TIME INT (SEC) X X	MESSAGE OR CONTROL NUMBER		CARD TYPE	CHECKED	PUNCHED	VERIFIED
1 2 3	4 5	6 7 8 9	10	11 12 13 14 15	16 17 18 19 20 21 22 23 24	25 26 27 28 29 30	31 32 33 34 35 36 37	38 39 40 41 42 43 44	45 46 47 48 49 50 51 52 53	54	55 56 57 58 59 60 61 62 63	64 65 66 67 68 69	70 71 73 73 74 75 76 77 78 79	80			

AEROSPACE 6600 TN ABW FORM 12 JUN 61

5.2 MISCELLANEOUS

The following information is used by the analyst:

a. Conversion Factors

b. Modified Julian Days

c. Oblate Spheroidal Earth Model Distance

d. Right Ascension of Greenwich

e. Satellite Elevation and Slant Range

f. Semi-major Axis vs. Period

g. Mathematical constants

h. Formulas

i. Minutes and seconds to degrees

5.2.1 Conversion Factors

TO CONVERT	INTO	MULTIPLY BY
D		
days	minutes	1,440.0
days	seconds	86,440.0
degrees (angle)	minutes	60.0
degrees (angle)	quadrants	0.01111
degrees (angle)	radians	0.01745
E		
earth radii	kilometers	6378.165
earth radii	miles (naut.)	3443.934
earth radii	miles (stat.)	3963.208
F		
feet	centimeters	30.48
feet	kilometers	3.048×10^{-4}
feet	meters	0.3048
feet	miles (naut.)	1.645×10^{-4}
feet	miles (stat.)	1.894×10^{-4}
feet/min	cms/sec	0.5080
feet/min	feet/sec	0.01667
feet/min	kms/hr	0.01829
feet/min	meters/min	0.3048
feet/min	miles/hr	0.01136
feet/sec	cms/sec	30.48
feet/sec	kms/hr	1.097
feet/sec	knots	0.5921
feet/sec	meters/min	18.29
feet/sec	miles/hr	0.6818
feet/sec	miles/min	0.01136

TO CONVERT	INTO	MULTIPLY BY
feet/sec/sec	cms/sec/sec	30.48
feet/sec/sec	kms/hr/sec	1.097
feet/sec/sec	meters/sec/sec	0.3048
feet/sec/sec	miles/hr/sec	0.6818
H		
hours	days	4.167×10^{-2}
hours	seconds	3,600.0
K		
kilograms	pounds	2.205
kilometers	earth radii	1.56785×10^{-4}
kilometers	feet	3,281.
kilometers	miles (naut.)	0.5299569
kilometers	miles (stat.)	0.6214
kilometers	yards	1,094.
knots	feet/hr	6,080.
knots	kilometers/hr	1.8532
knots	nautical miles/hr	1.0
knots	statute miles/hr	1.151
knots	yards/hr	2,027.
knots	feet/sec	1.689
M		
mean solar day	sidereal day	1.00273791
mean solar day	sidereal time	$24^h03^m56^s.555$
meters	feet	3.281
meters	kilometers	0.001
meters	miles (naut.)	5.396×10^{-4}
meters	miles (stat.)	6.214×10^{-4}

TO CONVERT	INTO	MULTIPLY BY
meters	yards	1.094
meters/min	feet/min	3.281
meters/min	feet/sec	0.05468
meters/min	kms/hr	0.06
meters/min	knots	0.03238
meters/min	miles/hr	0.03728
meters/sec	feet/min	196.8
meters/sec	feet/sec	3.281
meters/sec	kilometers/hr	3.6
meters/sec	kilometers/min	0.06
meters/sec	miles/hr	2.237
meters/sec	miles/min	0.03728
meters/sec/sec	ft/sec/sec	3.281
meters/sec/sec	kms/hr/sec	3.6
meters/sec/sec	miles/hr/sec	2.237
miles (naut.)	earth radii	2.9036×10^{-4}
miles (naut.)	feet	6,080.27
miles (naut.)	kilometers	1.853
miles (naut.)	meters	1,853.
miles (naut.)	miles (statute)	1.1516
miles (naut.)	yards	2,027.
miles (stat.)	earth radii	2.52321×10^{-4}
miles (stat.)	feet	5,280.
miles (stat.)	kilometers	1.609344
miles (stat.)	meters	1,609.
miles (stat.)	miles (naut.)	0.8684
miles (stat.)	yards	1,760.
miles/hr	feet/min	88.
miles/hr	feet/sec	1.467
miles/hr	kms/hr	1.609
miles/hr	kms/min	0.02682

TO CONVERT	INTO	MULTIPLY BY
miles/hr	knots	0.8684
miles/hr	meters/min	26.82
miles/hr	miles/min	0.01667
miles/hr/sec	feet/sec/sec	1.467
miles/hr/sec	kms/hr/sec	1.609
miles/hr/sec	meters/sec/sec	0.4470
miles/min	feet/sec	88.
miles/min	kms/min	1.609
miles/min	miles (naut.)/min	0.8684
miles/min	miles/hr	60.0
P		
pounds	kilograms	0.4536
R		
radians	degrees	57.30
radians	minutes	3,438.
radians	seconds	2.063×10^5
radians/sec	degrees/sec	57.30
radians/sec	revolutions/min	9.549
radians/sec	revolutions/sec	0.1592
revolutions	degrees	360.0
revolutions	radians	6.283
S		
sidereal day	mean solar days	0.99726957
sidereal day	mean solar time	$23^h 56^m 4^s.091$
Y		
yards	kilometers	9.144×10^{-4}
yards	meters	0.9144
yards	miles (naut.)	4.934×10^{-4}
yards	miles (stat.)	5.682×10^{-4}

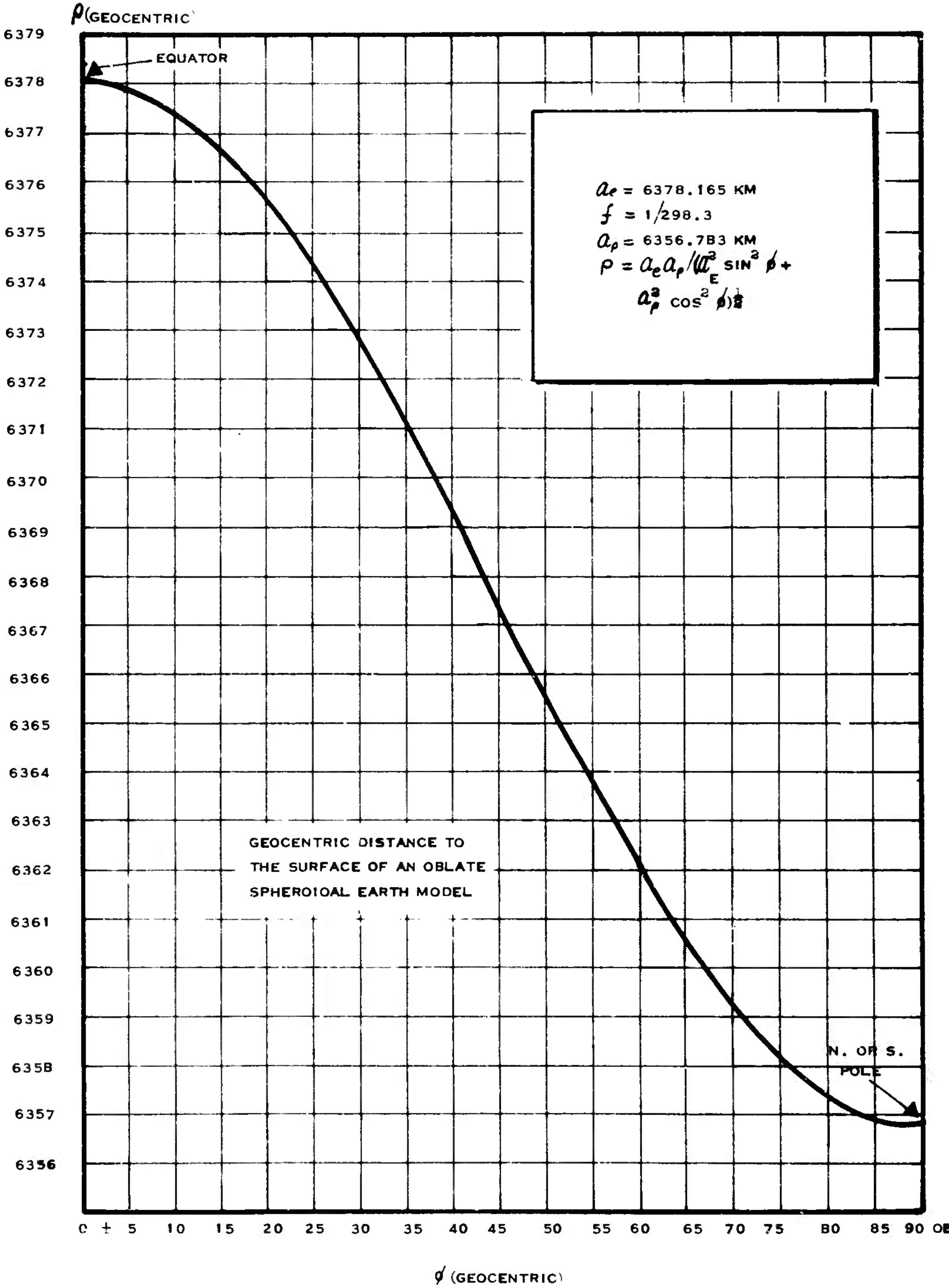
5.2.2 Modified Julian Days - 1964

DOM	JAN		FEB		MAR		APR		MAY		JUN	
	DOY	MJD	DOY	MJD	DOY	MJD	DOY	MJD	DOY	MJD	DOY	MJD
1	1	38395	32	38426	61	38455	92	38486	122	38516	153	38547
2	2	96	33	27	62	56	93	87	123	17	154	48
3	3	97	34	28	63	57	94	88	124	18	155	49
4	4	98	35	29	64	58	95	89	125	19	156	550
5	5	99	36	430	65	59	96	490	126	520	157	51
6	6	400	37	31	66	460	97	91	127	21	158	52
7	7	01	38	32	67	61	98	92	128	22	159	53
8	8	02	39	33	68	62	99	93	129	23	160	54
9	9	03	40	34	69	63	100	94	130	24	161	55
10	10	04	41	35	70	64	101	95	131	25	162	56
11	11	05	42	36	71	65	102	96	132	26	163	57
12	12	06	43	37	72	66	103	97	133	27	164	58
13	13	07	44	38	73	67	104	98	134	28	165	59
14	14	08	45	39	74	68	105	99	135	29	166	560
15	15	09	46	440	75	69	106	500	136	530	167	61
16	16	410	47	41	76	470	107	01	137	31	168	62
17	17	11	48	42	77	71	108	02	138	32	169	63
18	18	12	49	43	78	72	109	03	139	33	170	64
19	19	13	50	44	79	73	110	04	140	34	171	65
20	20	14	51	45	80	74	111	05	141	35	172	66
21	21	15	52	46	81	75	112	06	142	36	173	67
22	22	16	53	47	82	76	113	07	143	37	174	68
23	23	17	54	48	83	77	114	08	144	38	175	69
24	24	18	55	49	84	78	115	09	145	39	176	570
25	25	19	56	450	85	79	116	510	146	540	177	71
26	26	420	57	51	86	480	117	11	147	41	178	72
27	27	21	58	52	87	81	118	12	148	42	179	73
28	28	22	59	53	88	82	119	13	149	43	180	74
29	29	23	60	54	89	83	120	14	150	44	181	75
30	30	24			90	84	121	15	151	45	182	76
31	31	25			91	85			152	46		

5.2.2 Modified Julian Days - 1964 (Continued)

DOM	JUL		AUG		SEP		OCT		NOV		DEC	
	DOY	MJD	DOY	MJD	DOY	MJD	DOY	MJD	DOY	MJD	DOY	MJD
1	183	38577	214	38608	245	38639	275	38669	306	38700	336	38730
2	184	78	215	09	246	640	276	670	307	01	337	31
3	185	79	216	610	247	41	277	71	308	02	338	32
4	186	580	217	11	248	42	278	72	309	03	339	33
5	187	81	218	12	249	43	279	73	310	04	340	34
6	188	82	219	13	250	44	280	74	311	05	341	35
7	189	83	220	14	251	45	281	75	312	06	342	36
8	190	84	221	15	252	46	282	76	313	07	343	37
9	191	85	222	16	253	47	283	77	314	08	344	38
10	192	86	223	17	254	48	284	78	315	09	345	39
11	193	87	224	18	255	49	285	79	316	710	346	740
12	194	88	225	19	256	650	286	680	317	11	347	41
13	195	89	226	620	257	51	287	81	318	12	348	42
14	196	590	227	21	258	52	288	82	319	13	349	43
15	197	91	228	22	259	53	289	83	320	14	350	44
16	198	92	229	23	260	54	290	84	321	15	351	45
17	199	93	230	24	261	55	291	85	322	16	352	46
18	200	94	231	25	262	56	292	86	323	17	353	47
19	201	95	232	26	263	57	293	87	324	18	354	48
20	202	96	233	27	264	58	294	88	325	19	355	49
21	203	97	234	28	265	59	295	89	326	720	356	750
22	204	98	235	29	266	660	296	690	327	21	357	51
23	205	99	236	630	267	61	297	91	328	22	358	52
24	206	600	237	31	268	62	298	92	329	23	359	53
25	207	01	238	32	269	63	299	93	330	24	360	54
26	208	02	239	33	270	64	300	94	331	25	361	55
27	209	03	240	34	271	65	301	95	332	26	362	56
28	210	04	241	35	272	66	302	96	333	27	363	57
29	211	05	242	36	273	67	303	97	334	28	364	58
30	212	06	243	37	274	68	304	98	335	29	365	59
31	213	07	244	38			305	99			366	760

5.2.3 OBLATE SPHEROIDAL EARTH MODEL



5.2.4 Right Ascension of Greenwich, 0 Jan, 0000Z

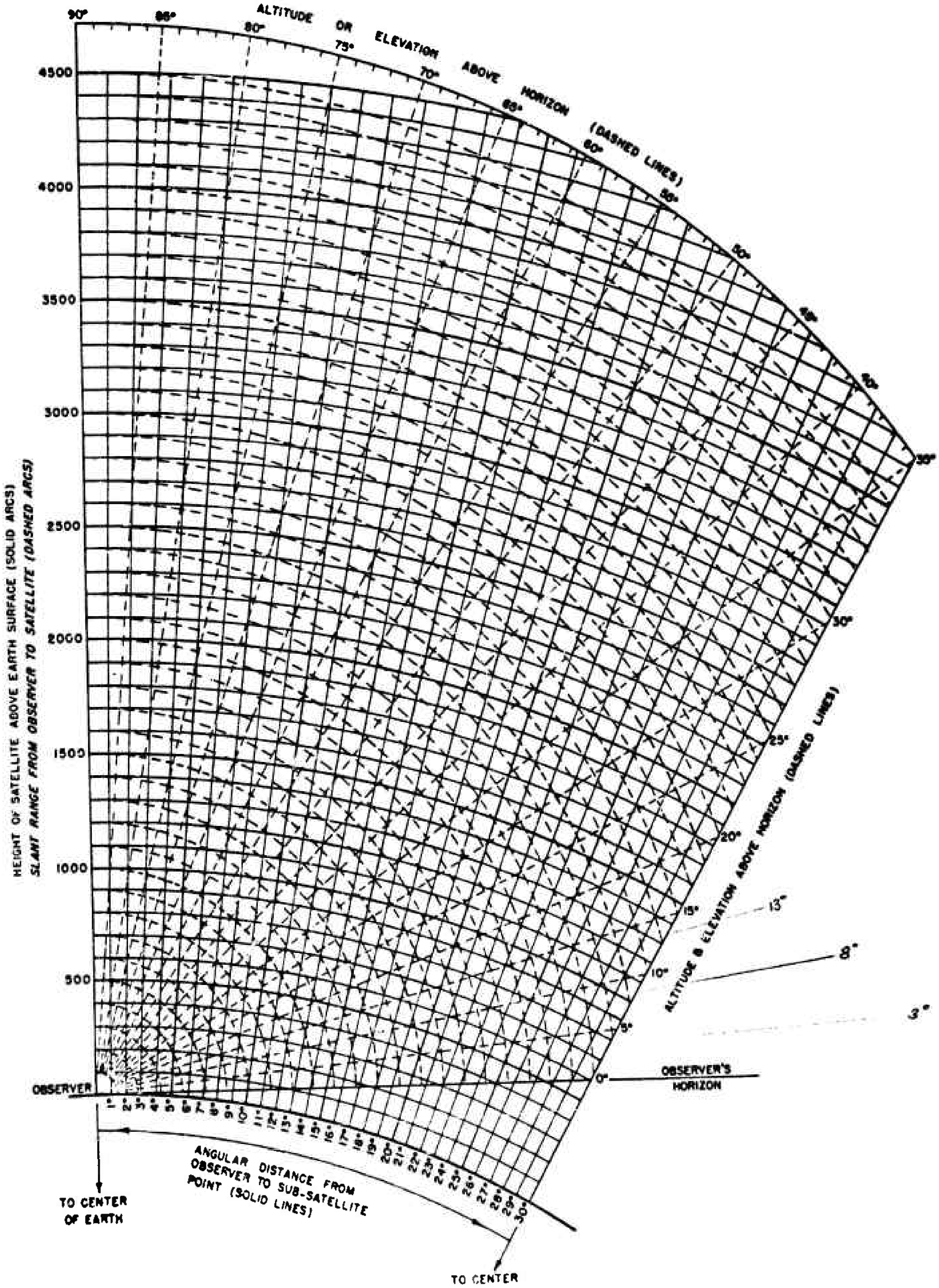
1957	99.3902
1958	99.1514
1959	98.9127
1960	98.6740
1961	99.4209
1962	99.1822
1963	98.9435
1964	98.7048
1965	99.4517
1966	99.2130
1967	98.9743
1968	98.7356
1969	99.4825
1970	99.2438

DEG.

5.2.5 SATELLITE ELEVATION AND SLANT RANGE

CHART FOR DETERMINING ELEVATION & SLANT RANGE OF SATELLITE

ALL DISTANCES ARE IN STATUTE MILES– 5 STATUTE MILES EQUAL APPROXIMATELY 8 KILOMETERS



5.2.6 SEMI-MAJOR AXIS VS. PERIOD

SEMI-MAJOR AXIS VS. PERIOD

PERIOD (MINS)	FRACTIONS OF MINUTES 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
80.	0.96426	0.96506	0.96586	0.96667	0.96747	0.96827	0.96907	0.96987	0.97067	0.97145
81.	0.97228	0.97308	0.97388	0.97467	0.97547	0.97627	0.97707	0.97787	0.97867	0.97946
82.	0.98026	0.98106	0.98185	0.98265	0.98345	0.98424	0.98504	0.98583	0.98663	0.98742
93.	0.98821	0.98901	0.98980	0.99059	0.99139	0.99218	0.99297	0.99376	0.99455	0.99535
84.	0.99614	0.99693	0.99772	0.99851	0.99930	1.00009	1.00087	1.00166	1.00245	1.00324
95.	1.00403	1.00481	1.00560	1.00639	1.00717	1.00796	1.00875	1.00953	1.01032	1.01110
86.	1.01189	1.01267	1.01345	1.01424	1.01502	1.01580	1.01659	1.01737	1.01815	1.01893
87.	1.01971	1.02050	1.02128	1.02206	1.02284	1.02362	1.02440	1.02518	1.02596	1.02674
88.	1.02751	1.02829	1.02907	1.02985	1.03063	1.03140	1.03219	1.03296	1.03373	1.03451
89.	1.03528	1.03606	1.03683	1.03761	1.03838	1.03916	1.03993	1.04070	1.04148	1.04225
90.	1.04302	1.04380	1.04457	1.04534	1.04611	1.04688	1.04765	1.04842	1.04920	1.04997
91.	1.05074	1.05151	1.05227	1.05304	1.05381	1.05458	1.05535	1.05612	1.05688	1.05765
92.	1.05842	1.05919	1.05995	1.06072	1.06148	1.06225	1.06302	1.06378	1.06455	1.06531
93.	1.06608	1.06684	1.06760	1.06837	1.06913	1.06989	1.07066	1.07142	1.07218	1.07294
94.	1.07370	1.07446	1.07523	1.07599	1.07675	1.07751	1.07827	1.07903	1.07979	1.08055
95.	1.08130	1.08206	1.08282	1.08358	1.08434	1.08510	1.08585	1.08661	1.08737	1.08812
96.	1.08888	1.08964	1.09039	1.09115	1.09190	1.09266	1.09341	1.09417	1.09492	1.09567
97.	1.09643	1.09718	1.09793	1.09869	1.09944	1.10019	1.10095	1.10170	1.10245	1.10320
98.	1.10395	1.10470	1.10545	1.10620	1.10695	1.10770	1.10845	1.10920	1.10995	1.11070
99.	1.11145	1.11220	1.11294	1.11369	1.11444	1.11519	1.11593	1.11668	1.11743	1.11817
100.	1.11892	1.11967	1.12041	1.12116	1.12190	1.12265	1.12339	1.12414	1.12488	1.12562
101.	1.12637	1.12711	1.12785	1.12860	1.12934	1.13008	1.13082	1.13157	1.13231	1.13305
102.	1.13379	1.13453	1.13527	1.13601	1.13675	1.13749	1.13823	1.13897	1.13971	1.14045
103.	1.14119	1.14193	1.14266	1.14340	1.14414	1.14488	1.14562	1.14635	1.14709	1.14783
104.	1.14856	1.14930	1.15003	1.15077	1.15151	1.15224	1.15298	1.15371	1.15444	1.15518
105.	1.15591	1.15665	1.15738	1.15811	1.15885	1.15958	1.16031	1.16104	1.16178	1.16251
106.	1.16324	1.16397	1.16470	1.16543	1.16617	1.16690	1.16763	1.16836	1.16909	1.16982
107.	1.17055	1.17127	1.17200	1.17273	1.17346	1.17419	1.17492	1.17564	1.17637	1.17710
108.	1.17783	1.17855	1.17928	1.18001	1.18073	1.18146	1.18219	1.18291	1.18364	1.18436
109.	1.18509	1.18581	1.18654	1.18726	1.18798	1.18871	1.18943	1.19015	1.19088	1.19160
110.	1.19232	1.19305	1.19377	1.19449	1.19521	1.19593	1.19666	1.19738	1.19810	1.19882
111.	1.19954	1.20026	1.20098	1.20170	1.20242	1.20314	1.20386	1.20458	1.20530	1.20601
112.	1.20673	1.20745	1.20817	1.20889	1.20960	1.21032	1.21104	1.21176	1.21247	1.21319
113.	1.21390	1.21462	1.21534	1.21605	1.21677	1.21748	1.21820	1.21891	1.21963	1.22034
114.	1.22106	1.22177	1.22248	1.22320	1.22391	1.22462	1.22534	1.22605	1.22676	1.22747
115.	1.22819	1.22890	1.22961	1.23032	1.23103	1.23174	1.23245	1.23316	1.23388	1.23459
116.	1.23530	1.23601	1.23672	1.23742	1.23813	1.23884	1.23955	1.24026	1.24097	1.24168
117.	1.24238	1.24309	1.24380	1.24451	1.24521	1.24592	1.24663	1.24734	1.24804	1.24875
118.	1.24945	1.25016	1.25087	1.25157	1.25228	1.25298	1.25369	1.25439	1.25509	1.25580
119.	1.25650	1.25721	1.25791	1.25861	1.25932	1.26002	1.26072	1.26143	1.26213	1.26283

5.2.6 SEMI-MAJOR AXIS VS. PERIOD (Continued)

SEMI-MAJOR AXIS VS. PERIOD

PERIOD (MINS)	FRACTIONS OF MINUTES 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
120.	1.26353	1.26423	1.26494	1.26564	1.26634	1.26704	1.26774	1.26844	1.26914	1.26984
121.	1.27054	1.27124	1.27194	1.27264	1.27334	1.27404	1.27474	1.27544	1.27614	1.27683
122.	1.27753	1.27823	1.27893	1.27963	1.28032	1.28102	1.28172	1.28242	1.28311	1.28381
123.	1.28450	1.28520	1.28590	1.28659	1.28729	1.28798	1.28868	1.28937	1.29007	1.29076
124.	1.29146	1.29215	1.29285	1.29354	1.29423	1.29493	1.29562	1.29631	1.29701	1.29770
125.	1.29839	1.29908	1.29978	1.30047	1.30116	1.30185	1.30254	1.30323	1.30393	1.30462
126.	1.30531	1.30600	1.30669	1.30738	1.30807	1.30876	1.30945	1.31014	1.31083	1.31152
127.	1.31220	1.31289	1.31358	1.31427	1.31496	1.31565	1.31633	1.31702	1.31771	1.31840
128.	1.31908	1.31977	1.32046	1.32114	1.32183	1.32252	1.32320	1.32389	1.32457	1.32526
129.	1.32594	1.32663	1.32731	1.32800	1.32868	1.32937	1.33005	1.33074	1.33142	1.33210
130.	1.33279	1.33347	1.33415	1.33484	1.33552	1.33620	1.33689	1.33757	1.33825	1.33893
131.	1.33961	1.34030	1.34098	1.34166	1.34234	1.34302	1.34370	1.34438	1.34506	1.34574
132.	1.34642	1.34710	1.34778	1.34846	1.34914	1.34982	1.35050	1.35118	1.35186	1.35254
133.	1.35321	1.35389	1.35457	1.35525	1.35593	1.35660	1.35728	1.35796	1.35863	1.35931
134.	1.35999	1.36066	1.36134	1.36202	1.36269	1.36337	1.36405	1.36472	1.36540	1.36607
135.	1.36675	1.36742	1.36810	1.36877	1.36944	1.37012	1.37079	1.37147	1.37214	1.37281
136.	1.37349	1.37416	1.37483	1.37551	1.37618	1.37685	1.37752	1.37820	1.37887	1.37954
137.	1.38021	1.38088	1.38155	1.38223	1.38290	1.38357	1.38424	1.38491	1.38558	1.38625
138.	1.38692	1.38759	1.38826	1.38893	1.38960	1.39027	1.39094	1.39161	1.39227	1.39294
139.	1.39361	1.39428	1.39495	1.39562	1.39628	1.39695	1.39762	1.39829	1.39895	1.39962
140.	1.40029	1.40095	1.40162	1.40229	1.40295	1.40362	1.40429	1.40495	1.40562	1.40628
141.	1.40695	1.40761	1.40828	1.40894	1.40961	1.41027	1.41094	1.41160	1.41226	1.41293
142.	1.41359	1.41426	1.41492	1.41558	1.41625	1.41691	1.41757	1.41823	1.41890	1.41956
143.	1.42022	1.42088	1.42154	1.42221	1.42287	1.42353	1.42419	1.42485	1.42551	1.42617
144.	1.42683	1.42749	1.42815	1.42881	1.42948	1.43013	1.43079	1.43145	1.43211	1.43277
145.	1.43343	1.43409	1.43475	1.43541	1.43607	1.43673	1.43738	1.43804	1.43870	1.43936
146.	1.44001	1.44067	1.44133	1.44199	1.44264	1.44330	1.44396	1.44461	1.44527	1.44593
147.	1.44658	1.44724	1.44789	1.44855	1.44921	1.44986	1.450[illegible]	1.45117	1.45183	1.45248
148.	1.45314	1.45379	1.45444	1.45510	1.45575	1.45641	1.45706	1.45771	1.45837	1.45902
149.	1.45967	1.46033	1.46098	1.46163	1.46229	1.46294	1.46359	1.46424	1.46489	1.46555
150.	1.46620	1.46685	1.46750	1.46815	1.46880	1.46945	1.47010	1.47076	1.47141	1.47206
151.	1.47271	1.47336	1.47401	1.47466	1.47531	1.47596	1.47661	1.47725	1.47790	1.47855
152.	1.47920	1.47985	1.48050	1.48115	1.48180	1.48244	1.48309	1.48374	1.48439	1.48503
153.	1.48568	1.48633	1.48698	1.48762	1.48827	1.48892	1.48956	1.49021	1.49086	1.49150
154.	1.49215	1.49279	1.49344	1.49409	1.49473	1.49538	1.49602	1.49667	1.49731	1.49796
155.	1.49860	1.49925	1.49989	1.50053	1.50118	1.50182	1.50247	1.50311	1.50375	1.50440
156.	1.50504	1.50568	1.50633	1.50697	1.50761	1.50825	1.50890	1.50954	1.51018	1.51082
157.	1.51146	1.51211	1.51275	1.51339	1.51403	1.51467	1.51531	1.51595	1.51659	1.51724
158.	1.51788	1.51852	1.51916	1.51980	1.52044	1.52108	1.52172	1.52236	1.52300	1.52363
159.	1.52427	1.52491	1.52555	1.52619	1.52683	1.52747	1.52811	1.52874	1.52938	1.53002

SEMI-MAJOR AXIS VS. PERIOD

FRACTIONS OF MINUTES

PERIOD (MINS)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
160.	1.53066	1.53130	1.53193	1.53257	1.53321	1.53385	1.53448	1.53512	1.53576	1.53639
161.	1.53703	1.53767	1.53830	1.53894	1.53957	1.54021	1.54085	1.54148	1.54212	1.54275
162.	1.54339	1.54402	1.54466	1.54529	1.54593	1.54656	1.54720	1.54783	1.54846	1.54910
163.	1.54973	1.55037	1.55100	1.55163	1.55227	1.55290	1.55353	1.55417	1.55480	1.55543
164.	1.55606	1.55670	1.55733	1.55796	1.55859	1.55922	1.55986	1.56049	1.56112	1.56175
165.	1.56238	1.56301	1.56364	1.56428	1.56491	1.56554	1.56617	1.56680	1.56743	1.56806
166.	1.56869	1.56932	1.56995	1.57058	1.57121	1.57184	1.57247	1.57310	1.57372	1.57435
167.	1.57498	1.57561	1.57624	1.57687	1.57750	1.57812	1.57875	1.57938	1.58001	1.58064
168.	1.58126	1.58189	1.58252	1.58315	1.58377	1.58440	1.58503	1.58565	1.58628	1.58691
169.	1.58753	1.58816	1.58878	1.58941	1.59004	1.59066	1.59129	1.59191	1.59254	1.59316
170.	1.59379	1.59441	1.59504	1.59566	1.59629	1.59691	1.59754	1.59816	1.59878	1.59941
171.	1.60003	1.60066	1.60128	1.60190	1.60253	1.60315	1.60377	1.60440	1.60502	1.60564
172.	1.60626	1.60689	1.60751	1.60813	1.60875	1.60938	1.61000	1.61062	1.61124	1.61186
173.	1.61248	1.61310	1.61373	1.61435	1.61497	1.61559	1.61621	1.61683	1.61745	1.61807
174.	1.61869	1.61931	1.61993	1.62055	1.62117	1.62179	1.62241	1.62303	1.62365	1.62427
175.	1.62489	1.62551	1.62613	1.62674	1.62736	1.62798	1.62860	1.62922	1.62984	1.63045
176.	1.63107	1.63169	1.63231	1.63292	1.63354	1.63416	1.63478	1.63539	1.63601	1.63663
177.	1.63724	1.63786	1.63848	1.63909	1.63971	1.64033	1.64094	1.64156	1.64217	1.64279
178.	1.64340	1.64402	1.64464	1.64525	1.64587	1.64648	1.64710	1.64771	1.64833	1.64894
179.	1.64955	1.65017	1.65078	1.65140	1.65201	1.65262	1.65324	1.65385	1.65447	1.65508
180.	1.65569	1.65630	1.65692	1.65753	1.65814	1.65876	1.65937	1.65998	1.66059	1.66121
181.	1.66182	1.66243	1.66304	1.66365	1.66427	1.66488	1.66549	1.66610	1.66671	1.66732
182.	1.66793	1.66854	1.66916	1.66977	1.67038	1.67099	1.67160	1.67221	1.67282	1.67343
183.	1.67404	1.67465	1.67526	1.67587	1.67648	1.67709	1.67769	1.67830	1.67891	1.67952
184.	1.68013	1.68074	1.68135	1.68196	1.68256	1.68317	1.68378	1.68439	1.68500	1.68560
185.	1.68621	1.68682	1.68743	1.68803	1.68864	1.68925	1.68986	1.69046	1.69107	1.69169
186.	1.69228	1.69289	1.69350	1.69410	1.69471	1.69531	1.69592	1.69653	1.69713	1.69774
187.	1.69834	1.69895	1.69955	1.70016	1.70076	1.70137	1.70197	1.70258	1.70318	1.70379
188.	1.70439	1.70500	1.70560	1.70621	1.70681	1.70741	1.70802	1.70862	1.70922	1.70983
189.	1.71043	1.71103	1.71164	1.71224	1.71284	1.71345	1.71405	1.71465	1.71525	1.71586
190.	1.71646	1.71706	1.71766	1.71827	1.71887	1.71947	1.72007	1.72067	1.72127	1.72188
191.	1.72248	1.72308	1.72368	1.72428	1.72488	1.72548	1.72608	1.72668	1.72728	1.72788
192.	1.72848	1.72908	1.72968	1.73028	1.73088	1.73148	1.73208	1.73268	1.73328	1.73388
193.	1.73448	1.73508	1.73568	1.73628	1.73688	1.73747	1.73807	1.73867	1.73927	1.73987
194.	1.74047	1.74106	1.74166	1.74226	1.74286	1.74345	1.74405	1.74465	1.74525	1.74584
195.	1.74644	1.74704	1.74764	1.74823	1.74883	1.74943	1.75002	1.75062	1.75121	1.75181
196.	1.75241	1.75300	1.75360	1.75419	1.75479	1.75539	1.75598	1.75658	1.75717	1.75777
197.	1.75836	1.75896	1.75955	1.76015	1.76074	1.76134	1.76193	1.76253	1.76312	1.76371
198.	1.76431	1.76490	1.76550	1.76609	1.76668	1.76728	1.76787	1.76846	1.76906	1.76965
199.	1.77024	1.77084	1.77143	1.77202	1.77261	1.77321	1.77380	1.77439	1.77498	1.77558

5.2.7 Mathematical Constants

5.2.7.1 Earth Constants

The gravitational potential of the earth for general perturbations calculations is defined by:

$$U = \frac{GM_{\oplus}}{r} \left[1 - \sum_{n=2}^{\infty} J_n \left(\frac{a_e}{r} \right)^n P_n \ (\sin \phi) \right] \quad (1)$$

, where

$GM_{\oplus}$, the geocentric gravitational constant, (2)

$= 3.986032 \times 10^{20}$ cm^3/sec^2. (3)

a_e, the mean equatorial earth radius,

$= 6378.165$ km

r = the radial distance from the dynamical center is a_e units

ϕ = the geocentric latitude

and P_n $(\sin \phi)$ is the Legendre polynomial.

The zonal harmonic coefficients are:

$J_2 = 1082.30 \times 10^{-6}$ $(3/2\ J_2 = J)$

$J_3 = -2.3 \times 10^{-6}$ $(5/2\ J_3 = H)$

$J_4 = -1.8 \times 10^{-6}$ $(-35/8\ J_4 = D)$

and $(-15/4\ J_4 = K)$

$J_{n>4}$ are not considered.

f, the flattening of the earth (implicit in all calculations for U values, and used in all geometrical calculations),

$= 1/298.30 = 0.0033523$.

5.2.7.2 Sidereal Constants.

ω, the earth sidereal rotational rate,

= 1.0027379093 mean sidereal rotations/mean solar day

θ_G, the mean right ascension of the Greenwich meridian at 0^h U.T. on 0 January,

= 98.70478 degrees (1964)

= 99.45171 degrees (1965)

= 99.21298 degrees (1966)

---

(1) The special perturbations programs used for precision satellite position determination apply geopotential functions which are both longitude and latitude dependent. The Kozai zonal coefficients (SAO Special Report No. 101, 31 July 1962) are generally used.

(2) The values of $GM_{\oplus}$, a_e, f, J_2, J_3, and J_4 are those recommended by Kaula (NASA TND-1848, May 1963).

(3) In SPACETRACK computations, k_e is used, where

$k_e = (GM_{\oplus})^{\frac{1}{2}} = 0.07436662$ earth-radii/minute.

(The value 0.07436574 was used prior to March 1964.)

In general perturbations programs $k_e\sqrt{\mu}$ and k_e are assumed to be equal.

5.2.8 Formulas

5.2.8.1 Definition of Symbols

a	semi-major axis (units of earth radii unless otherwise specified)
b	semi-minor axis
β	difference between orbital plane as defined by elements and orbital plane defined by ovservation
C_A	anomalistic drag term (days/rev^2)
C_N	nodal drag term (days/rev^2)
D_A	anomalistic drag acceleration term (days/rev^3)
D_N	nodal drag acceleration term (days/rev^3)
e	eccentricity
h	apogee height
i	inclination
k	geocentric gravitational constant ($k = 84.48932$ or 205.82)
L_o	mean longitude at epoch
λ_{W_i}	injection longitude (west)
λ_{W_o}	longitude of the theoretical ascending node on revolution zero
M	mean anomaly
Ω_t	right ascension at any time t
Ω_o	right ascension at ascending node
ω	argument of perigee
ω_1	argument of perigee at time $T_o + \Delta t$.
ω_o	nominal argument of perigee
$\dot{\omega}$	time derivative of ω

p	semi-latus rectum
P_A	anomalistic period
P_N	nodal period
ϕ_i	injection latitude
q	perigee height
r	distance from center of earth to satellite
$\bar{r}$	observation position vector of satellite
R	revolutions
ΔR	revolution from T_o to T
T	time at ΔR revolutions since T_o
T_i	time of injection (days)
T_o	epoch time
$\theta_{G_{T_O}}$	right ascension of Greenwich at T_o
v	angle between perigee point and some specified point in the orbit
V_a	velocity at apogee
$(V_c)_a$	circular velocity of a satellite at a height equal to apogee height
$(V_c)_p$	circular velocity of a satellite at a height equal to perigee height
V_p	velocity at perigee
$\bar{w}$	unit vector normal to orbital plane

5.2.8.2 Miscellaneous Formulas

$$a = \frac{h + q}{2}$$

$$\beta = \sin^{-1} \frac{1}{r} (\bar{r} \cdot \bar{w})$$

$$e = \left[1 - \frac{b^2}{a^2} \right]^{\frac{1}{2}}$$

$$e = 1 - \frac{q}{a} = \frac{h - q}{q + h} = \frac{(V_p)^2}{(V_c)^2_p} - 1, \text{ or } 1 - \frac{(V_a)^2}{(V_c)^2_a}$$

$$L_o = M + \omega \pm \Omega_o \ ; \quad + \Omega_o, \text{ if } i \leq 90^\circ$$

$$\Omega_t = \Omega_o + \dot{\Omega}_o (\Delta t) + \tfrac{1}{2} \ddot{\Omega} (\Delta t)^2; \ 0^\circ \leq \Omega < 360^\circ$$

$$\dot{\Omega} = \frac{- 9.96 \ a^{-7/2} \cos i}{(1 - e^2)^2}$$

$$\omega = \omega_o + \dot{\omega}_o (\Delta t) + \tfrac{1}{2} \ddot{\omega}_o (\Delta t)^2; \text{ where } 0^\circ \leq \omega < 360^\circ$$

$$\omega_1 = \omega + \dot{\omega} \Delta t$$

$$\dot{\omega} = \frac{4.98 \ a^{-7/2} (5 \cos^2 i - 1)}{(1 - e^2)^2}$$

$P_A = \left(\frac{a}{k}\right)^{3/2}$, P_A is in minutes; if a is in ER, let k = 84.48932

if a is in Stat. miles, let k = 205.82

or P_A = .058672947 $(a)^{3/2}$ (P_A is in days, a in ER)

$$P_N = \left(\frac{360}{360 + \dot{\omega} P_A} \right) P_A$$

$$q = a (1 - e)$$

$$r = \frac{p}{1 + e \cos v}$$

$$T = T_o + P_N (\Delta R) + C_N (\Delta R)^2 + D_N (\Delta R)^3$$

$$\Delta t = \frac{P_A M;}{2\pi} \qquad (2\pi = 6.2831853)$$

$$V_a h = V_p q$$

5.2.9 Minutes and Seconds to Degrees

Minutes to Decimal of Degree	Mins or Sec.	Seconds to Decimal of Degree	Minutes to Decimal of Degree	Mins or Sec.	Seconds to Decimal of Degree
.00000	00	.00000	.50000	30	.00833
.01667	01	.00028	.51667	31	.00861
.03333	02	.00056	.53333	32	.00889
.05000	03	.00083	.55000	33	.00917
.06667	04	.00111	.56667	34	.00944
.08333	05	.00139	.58333	35	.00972
.10000	06	.00167	.60000	36	.01000
.11667	07	.00194	.61667	37	.01028
.13333	08	.00222	.63333	38	.01056
.15000	09	.00250	.65000	39	.01083
.16667	10	.00278	.66667	40	.01111
.18333	11	.00306	.68333	41	.01139
.20000	12	.00333	.70000	42	.01167
.21667	13	.00361	.71667	43	.01194
.23333	14	.00389	.73333	44	.01222
.25000	15	.00417	.75000	45	.01250
.26667	16	.00444	.76667	46	.01278
.28333	17	.00472	.78333	47	.01306
.30000	18	.00500	.80000	48	.01333
.31667	19	.00528	.81667	49	.01361
.33333	20	.00556	.83333	50	.01389
.35000	21	.00583	.85000	51	.01417
.36667	22	.00611	.86667	52	.01444
.38333	23	.00639	.88333	53	.01472
.40000	24	.00667	.90000	54	.01500
.41667	25	.00694	.91667	55	.01528
.43333	26	.00722	.93333	56	.01556
.45000	27	.00750	.95000	57	.01583
.46667	28	.00778	.96667	58	.01611
.48333	29	.00806	.98333	59	.01639

5.3 OBSERVATION REPORT FORMATS

Observations are received in the following formats:

a. Standard A

b. Station 315 old format

c. Holloman

d. Moonwatch

e. SAO Baker-Nunn

f. SATEV (Muedon)

g. SATOF

h. SATUG

i. Trinidad

j. Syncom

k. 681/682

l. Millstone

Each format is given, and the procedures for handlogging the information onto standard Observation cards are described. (See section 5.1 for appropriate form).

5.3.1 Standard A Format

The following stations use the Standard A Format:

a. Shemya 345

b. Shemya 316

c. Turkey 337

d. Turkey (new) 315

e. Laredo

f. Moorestown

g. SPASUR

h. Minitrack

i. Prince Albert

j. BMEWS

k Trinidad

5.3.1.1 Example

```
$$$$$
tSTAa  OBJEC  YMoDa
HHMMSSsss  DDdddd  DDDdddd  NNNNNnn  NNnnnnS  HHccc
)))))
```

Line	Code	Meaning
1	$$$$$	Connecting call code
2	t	Observation type (see figure 5.1)
	STA	SPADATS sensor number
	a	Observation accuracy/signal strength
	OBJEC	SPADATS object number
	YMoDa	Date of observation
3	HHMMSSsss	Time of observation
	DDdddd/	Elevation
	(DDdddS)	Declination (0 = north, 1 = south for last digit)
	DDDdddd/	Azimuth
	(HHMMSSs)	Right Ascension
	NNNNNnn	Slant range (nautical miles)
	NNnnnnS	Range rate (nautical miles/second), sign (S): 0 = +, 1 = -, 2 = unassigned
	HHccc	Hit count (HH) and check sum (ccc)
4	)))))	Disconnect call code

5.3.1.2 Handlogging Procedures

1. First line is the connecting call code and is not used in manual processing.
2. Second line:
   a. First digit of the word is the code for the observation type. See figure 5.1 for the associated two-digit code to be logged in cc 4-5. The next three digits are the SPADATS sensor number; log zero in cc 6 and the number in cc 7-9. The last digit, accuracy, is logged in cc 10.
   b. Second word is the SPADATS object number; log the last three digits in cc 1-3.
   c. Date of observation is the third word and is logged in cc 11-15.

3. Third line (first data line):

   a. Log the first word, time of observation, in cc 16-24.

   b. The second and third words represent elevation and azimuth unless the observation type is zero or two (1st digit second line). In that case, they represent declination and right ascension.

      (1) Log elevation, second word, in cc 25-30. Log azimuth, third word, in cc 31-37.

      (2) Log the first five digits of declination in cc 25-29 and add a zero in cc 30. If the last digit of this second word is a one, an eleven punch is needed in cc 25. Log right ascension, third word, in cc 31-37. An eleven overpunch is always necessary in cc 31 when the report is in declination and right ascension.

   c. Slant range, the fourth word, is reported in nautical miles which must be converted to kilometers. Multiply the digits by 1.852. The decimal point falls between the fifth and sixth digit of the message. Range rate, fifth word, is reported in nautical miles per second. The first six digits are multiplied by 1.852, the decimal point falls between the second and third digit of the message. The seventh digit is a sign -- if it is a one, an eleven overpunch is needed in cc 45; if it is a zero, plus is understood and no overpunch is needed.

4. The classification (U or C) as indicated in the message text must be logged in cc 71.

Figure 5.1

Observation Type Code for Standard A Reporting Format

INPUT (1st digit, line two)	OUTPUT (cc 4-5)	INSTRUMENTATION/FIELDS REPORTED
0	01	Optical-right ascension/declination
1	01	Optical-elevation/azimuth
2	16	Baker-Nunn-right ascension/dec.
3	25	Radar-el/az/slant range/range rate
4	22	Radar-el/az/slant range
5	51	Radiometric-el/az
6	25	BMEWS-Site 1, Site 2
7	51	SPASUR
8	21	FPS-17-el/az/slant rante/range rate
9	41	Doppler-range rate

5.3.2 Station 315 Old Format

5.3.2.1 Example

```
SYrMo   MessgNr
XXX     OBJ   XXX   DaHHMMSSs   NNNNX   XX
bt
```

Line	Code	Meaning
1	S	Station indicator
	YrMo	Year and month of observations
	MessgNr	Message number
2	XXX	Line number of observation
	OBJ	SPADATS object number
	XXX	Elevation and azimuth
	DaHHMMSSs	Day and time of observation
	NNNN	Slant range (nautical miles)
	X	End of line (for handlogging purposes)
	XX	Doppler channel
3	bt	End of message

5.3.2.2 Handlogging Procedures

1. First digit of first line is station indicator, and in this case would be logged as station 0315 in cc 6-9. The second two digits are the year of observation, and the last digit is logged in col 11. The last two digits of the first word is the month, and is logged in cc 12-13.
   a. The second word of the first line is unused for logging purposes.
2. Second line (first data line).
   a. First word is unused for manual processing.
   b. Second word is the SPADATS Object number and is logged in cc 1-9.
   c. Third word is elevation and azimuth, and is logged in cc 25-30, 31-37. (See 315 Handbook).
   d. Fourth word is day and time of observation. Log the first two digits in cc 14-15. Log the time of the observation (next seven digits) in cc 16-22, adding zeros in cc 23-24.

e. Slant range, the fifth word, is reported in nautical miles which must be converted to kilometers. Multiply the digits by 1.852, and log in cc 38-44. The last character of the fifth word is not logged.

f. Sixth word (two digits) is not used at SPADATS.

3. The type is 21, and is logged in cc 4-5, if slant range is omitted, log type 01 in cc 4-5.

5.3.3 Holloman AFB Format

5.3.3.1 Example

DAY OBJECT HH MM SS.s DDD.dd DD.dd

Line	Code	Meaning
1	DAY	Zebra Day of Observation
	OBJECT	SPADATS Object Number
	HH MM SS.s	Time of Observation
	DDD.dd	Azimuth (degrees)
	DD.dd	Elevation (degrees)

5.3.3.2 Handlogging Procedures

1. SPADATS sensor number is reported in the message text. Sensor number is 050. Log in cc 7-9, preceded by a 0 in cc 6.
2. Log type 01 in cc 4-5, and 0 for accuracy in cc 10.
3. Zebra day is reported. Convert to current date using calendar, and log in cc 11-15.
4. The remaining fields are described in the message. Log in appropriate columns.
5. Classification (U or C) as indicated on the message is logged in cc 71.

5.3.4 Moonwatch Format

5.3.4.1 Example

SENSORNAME RSTAT OBJEC YMoDa EHHMM SSsss DDDmm UDDmm CCCCC

Line	Code	Meaning
1	SENSOR NAME	
	R	Reporting Method
	STAT	SAO Sensor Number
	OBJEC	SAO Satellite # International Designation, Yr. of Launch, launch number, and piece #
	YMoDa	Date of Observation
	E	Epoch of Star charts
	HHMM	Time of Observation (hours and minutes)
	SSsss	Time of Observation (seconds)
	DDDmm	Azimuth or Right Ascension (If R.A. HHMMm)
	U	Unused digit if elevation
	DDmm	Elevation or Declination (If Dec. SDDmm, 0 = north, 1 = south in first digit)
	CCCCC	Check Group. Sum of all digits in corresponding column. Units digit only, tens digit not carried forward.

5.3.4.2 Handlogging Procedures

1. The first word is the alphabetic sensor name. It is not logged.
2. The first digit of the second word is the reporting method. If the digit is zero, the observation is in elevation and azimuth. If the digit is one, the observation is reported in right ascension and declination. The next four digits is the SAO sensor number, this must be converted to SPADATS station number. Log in cc 6-9.
3. The third word is the object's international designation. Convert to SPADAT object number, and log in cc 1-3.
4. The fourth word is the date of observation and is logged in cc 11-15.

5. The first digit of the fifth word is Epoch of Star Charts.

   0 - Present

   1 - 1855

   2 - 1875

   3 - 1900-1920

   4 - 1950

   Epoch of Star Charts is logged in cc 70. The remaining four digits and all the digits of word six is time of observation, log in cc 16-24.

6. The seventh word is azimuth or right ascension. If right ascension, log the first four digits in cc 31-34, multiply the last digit by 60 and log the result in cc 35-37. (Right ascension is always indicated by an eleven punch in cc 31). If the first digit of the second word is 0, the observation will be in azimuth, log the first three digits in cc 31-33. Convert the next two digits to decimal of degree by using the table in section 5.2.9, and log in cc 34-37.

7. The eight word is elevation or declination. If elevation is indicated by reporting method, the first digit is unused. Log the n xt two digits in cc 25-26. Convert the last two digits to decimal of degree by using table five, and log in cc 27-30. If declination is indicated, first digit is sign (1 indicates an eleven punch in cc 25, 0 is plus and is understood). Log next two digits in cc 25-26, and convert the last two digits to decimal of degree by using the table in section 5.2.9, and log in cc 27-30.

8. The ninth word is the check sum and is not used in handlogging.

9. The type is 01, and is logged in cc 4-5.

10. The accuracy is zero, and is logged in cc 10.

11. The classification (U or C) as indicated in the message must be logged in cc 71.

5.3.5 SAO Baker-Nunn Format

Baker-Nunn Sensors are as follows:

B-N Sensor Number	Name	SPADATS Sensor Number
01	Organ Pass	0033
02	Olifants Fontain	0034
03	Woomera	0035
04	San Fernando	0036
05	Tokyo	0037
06	Nainital	0041
07	Arequipa	0038
08	Shiraz	0042
09	Curacao	0045
10	Jupiter	0044
11	Villa Dolores	0046
12	Maui	0047
13	*Edwards	0030
14	*Cold Lake	0032
15	*Harestua	0029
16	Santiago	inactive
17	*Sand Island	0031

*Non-SAO station

5.3.5.1 Example

```
$$$$$   YrMoDaXXXX
222St   YMoDa
OBJEC   PIECE   WHHMM   SSsss   HHMMm   SDDMM   CCCCC
                WHHMM   SSsss   HHMMm   SDDMM   CCCCC
YMoDa
OBJEC   PIECE   WHHMM   SSsss   HHMMm   SDDMM   CCCCC
)))))
```

Line	Code	Meaning
1	$$$$$	Connecting Call Code
	YrMoDaXXXX	Message Date/Control Number
2	222	Format Code Indicator
	St	B-N Sensor #
	YMoDa	Date of Observation
3	OBJEC PIECE	Satellite # International Designation (Year of Launch, Launch # or Greek letter, and piece in group)
	W	Value of culmination time difference
	HHMMSSsss	Time of Observation

Line	Code	Meaning
	HHMMm	Right Ascension
	S	Sign (0 = +, 1 = minus)
	DDMM	Declination
	CCCCC	Check group. Sum of all digits in corresponding column. Units digit only, tens digit not carried forward.
4		Additional observation.
5	YMoDa	Designates change in date.
6		Observation (see line 3)
7	)))))	Disconnect Call Code.

5.3.5.2 Handlogging Procedures

1. The first line of five dollar signs and the message date/control number is not used in manual processing.
2. Second line:
   a. First word is the format code indicator, followed by the Baker-Nunn sensor number. Convert the two digit sensor number to the SPADATS sensor number shown on the preceding page and log in cc 6-9.
   b. The second word, date of observation, is logged in cc 11-15.
3. Third line:
   a. The first two words are the object's international designation; convert to SPADATS object number, using Satellite table, and log in cc 1-3.
   b. The first digit of word three is not used. Log the remainder of the word, and word four, time in cc 16-24.
   c. Right ascension is the fourth word. Log the first four digits in cc 31-34. Multiply the fifth digit by 60 and log the result in 35-37. An eleven overpunch must be logged in cc 31.
   d. The first digit of word six, declination, is the sign; if it is a one, an eleven overpunch is needed in cc 25, but if it is a zero no overpunch is needed. Log the next two digits in cc 25-26. Convert the next two digits to decimal of degree (section 5.2.9) and log in cc 27-30.
   e. The last word is unused in handlogging.
   f. Baker-Nunn is type 16, and is logged in cc 4-5. Log (U or C) as classification in message indicates in cc 71.

5.3.6 SATEV Format

The following is a list of COSPAR Station numbers with the corresponding SPADATS Station numbers.

COSPAR	SPADAT
3101	0075
3102	0076
3103	0079
3104	0080
3129	0081
3130	0082
3131	0083

5.3.6.1 Example

```
SATEV   STATt   OBJEC   rMoDa
HHMMS   SssDD   DMM//   DDMM/
bt
```

Line	Code	Meaning
1	SATEV	Format Code Indicator
	STAT	COSPAR Sensor #
	t	Observation type (See figure 5.2)*
	OBJEC	International Designation (sat. #) Yr of launch, launch number, piece in group.
	r	Data Type Code (see figure 5.2)**
	MoDa	Date of Observation
2	HHMMSSss	Time of Observation
	DDDMM//	Azimuth
	DDMM/	Elevation
3	bt	end observation

5.3.6.2 Handlogging Procedures

1. First word of line is format indicator and is not used in handlogging.
   a. The first four digits of second word is COSPAR sensor number. Convert to SPADATS sensor number using COSPAR sensor listing, above, and log in cc 6-9. The last digit is observation type code. (figure 5.2). Log 01, type, in cc 4-5.

b. Convert the third word, satellite number, to SPADATS object number using satellite table.

c. The first digit of word four is data type. (Figure 5.2) The last four digits are month and day of observations. Log in cc 12-15. The year is understood to be the current year, and is logged in cc 11.

2. Second line:

   a. Log the first five digits of word one and the next three digits of word two, time of observation, in cc 16-23 adding 0 in cc 24.

   b. Azimuth is the last two digits of word two and the first digit of word three, log in cc 31-33. If the data type is 2 the next two digits should be converted to decimal of degrees using the table in section 5.2.9, and logged in cc 34-37.

   c. Elevation is word three, log the first two digits in cc 25-26. If 2 is the data type, convert the last two digits to decimal of degree using the table in section 5.2.9, and log in 27-30. If 1 is the data type, log the digits in cc 27-28 adding 0 in cc 29-30.

3. If reporting type is 1, SATEV may omit the last digit of azimuth and elevation, in which case the minutes are in decimal of degree. Slashes are between and at the end of observation parameters.

4. Log 0 in cc 10 for observation accuracy, and the classification (U or C) as indicated on the message in cc 71.

Figure 5.2

*Observation Type Coded As:

1 - photographic; cinetheodolite

2 - photographic; fixed camera or small telescope

3 - photographic; tracking camera or telescope

4 - photographic; telescope

5 - Visual; naked eye or binoculars

6 - Visual; telescope (low power)

7 - Visual; telescope

8 - Visual; theodolite

9 - Visual; telescope

0 - other instrument or unknown

**Data Type Coded As:

1 - Azimuth/Elevation (degrees and thousandths of degree)

2 - Azimuth/Elevation (degrees, minutes, tenths of minutes)

3 - Equatorial (right ascension/declination) Epoch 1950.

4 - Equatorial (right ascension/declination) Epoch of date.

5 - Equatorial (right ascension/declination) Epoch of BD chart 185

6 - Equatorial (right ascention/declination) Epoch of CD chart 1575.

5.3.7 SATOF Format

5.3.7.1 Example

STATION DaHHx MMSSs HHMMm SDDMM IBbCC

Line	Code	Meaning
1	STATION	Station Name
	Da	Day of Observation
	HH	Hour of Observation
	x	Unused Digit
	MMSSs	Minutes and Seconds of Observation
	HHMMm	Right Ascension
	S	Sign
	DDMM	Declination
	I	Accuracy of observation
	B	Stellar Magnitude
	b	Tenths of Magnitude
	CC	Check Sum (Sum of all digits in observation)

5.3.7.2 Handlogging Procedures

1. The first word is station name. Convert to SPADATS sensor number, and log in cc 6-9.
2. Day of observation, first two digits of word two, is logged in cc 14-15. Hour of observation is the third and fourth digit, log in cc 16-17. Current year and month are logged in 11-13. The last digit of word two is unused.
3. Log the third word, minutes/and seconds of observation, in cc 18-22 adding 0 in cc 23-24.
4. Log the first four digits of word four, right ascension in cc 31-34, multiply the last digit by 60 and log the result in cc 35-36, adding 0 in cc 37. Right ascension is always indicated by an eleven punch in cc 31.

5. First digit of word five is sign. 0 signifies plus and is not logged. 1 indicates minus and an eleven punch is logged in cc 25. Log the next two digits in cc 25-26. Convert the last two digits (section 5.2.9) and log in cc 27-30. If the units digit of the minute field is an x, the tenths position is tenths of degree. Log digit in cc 27.
6. First digit of last word is observation accuracy. Log in cc 10.
7. Type is 01, and is logged in cc 4-5.
8. Object number will be in the message text. Log in cc 1-3.
9. Classification (U or C) as indicated on message is logged in cc 71.

5.3.8 SATUG Format

5.3.8.1 Example

STATION DaHHx MMSSs DDDdx DDdxx IBbCC

Line	Code	Meaning
1	STATION	Station Name
	Da	Day of Observation
	HH	Hour of Observation
	x	Unused Digit
	MMSSs	Minutes & Seconds of Observation
	DDDd	Azimuth
	x	Unused Digit
	DDd	Elevation
	xx	Unused Digits
	I	Accuracy of Observation
	B	Stellar Magnitude
	b	Tenths of Magnitude
	CC	Check Sum (Sum of all digits in observation)

5.3.8.2 Handlogging Procedures

1. Station name, first word, is converted to SPADATS sensor number and logged in cc 6-9.
2. The first two digits of word two is day of observation. Log in cc 14-15. Current month and year is logged in cc 11-13. Hours of observation is the third and fourth digit, and is logged in cc 16-17. Last digit of group is unused.
3. Minutes and seconds, word three, is logged in cc 18-22 adding 0 in cc 23-24.
4. Log the first four digits of word four, azimuth, in cc 31-34 adding 0 in cc 35-37. Last digit of group is unused.
5. Elevation, word five, is logged in cc 25-27 adding 0 in cc 28-30. The last two digits of group are not used.

6. Accuracy of observation, first digit of last word is logged in cc 10. Remaining digits are unused.
7. Type is 01. Log in cc 4-5.
8. Satellite number will be in message text. Log in cc 1-3.
9. Classification (U or C) as indicated on message is logged in cc 71.

5.3.9 Trinidad Format

5.3.9.1 Example

```
$$$$$
SS511    OBJty   STATa   YMoDa
HHMMSS.ss    DD.d   DDD.dd   NNNN    C
)))))
```

Line	Code	Meaning
1	$$$$$	Connecting Call Code
2	SS511	Format Code Indicator
	OBJ	SPADATS Obj #
	ty	Observation type
	STAT	SPADATS Sensor #
	a	Observation Accuracy
	YMoDa	Date of Observation
3	HHMMSS.ss	Time of Observation
	DD.d	Elevation (degrees)
	DDD.dd	Azimuth (degrees)
	NNNN	Slant Range (Nautical Miles)
	C	End of Line Indicator
4	)))))	Disconnect Call Code

5.3.9.2 Handlogging Procedures

1. First line ($$$$$) is not used in handlogging.
2. Second line:
   a. The first word of line two is the format indicator and is unused.
   b. The first three digits of word two is SPADATS object number, log in cc 1-3. The last two digits of word two is observation type and is logged in cc 4-5.
   c. SPADATS Sensor number, the first four digits of word three, is logged in cc 6-9.
   d. The last word of line two is date of observation, and is logged in cc 11-15.

3. Third line:
   a. The first word is the time of observation and is logged in cc 16-23 adding a 0 in cc 24.
   b. The second word of line three is elevation and is logged in cc 25-27 adding 0 in cc 28-30.
   c. Azimuth, the third word, is logged in cc 31-34, adding 0 in cc 35-37.
   d. The fourth word is slant range reported in nautical miles. Convert the four digits to kilometers by multiplying by 1.852, and log the result in cc 38-44.
   e. The last word, one digit, is unused in manual processing.
4. Trinidad may submit observations without slant range, in which case type 01 is logged in cc 4-5.
5. The classification (U or C) is logged in cc 71. Classification is indicated on the message.

5.3.10 SYNCOM II Format

The following is a list of Syncom Station names with the corresponding SPADATS Station numbers:

SYNCOM STATION NAME	SPADATS STATION NUMBER
SYNT1H	0909
SYNCS2	0901
SYNCS3	0902
SYNCS4	0903
SYNCS5	0904

5.3.10.1 Example

```
))))) OBJEC
STATNA   YYMMDD   HHMM   SSsss   T        DDd
STATNA   YYMMDD   HHMM   SSsss   T  KKKKKKKkkk
STATNA   YYMMDD   HHMM   SSsss   T     Kkkkkk
STATNA   YYMMDD   HHMM   SSsss   T       DDDd
$$$$$
```

Line	Code	Meaning
1	)))))	Precedes Object #
	OBJEC	International Designation Satellite #
2-5	STATNA	Station Name
	YYMMDD	Date of Observation
	HHMMSSsss	Time of Observation
	T	Type Code (See Figure 5.3)
	XXXXXXXXX	Data (3-9 characters: see Figure 5.3)
6	$$$$$	End of Observation

5.3.10.2 Handlogging Procedures

1. The first word of line one is unused in handlogging. The second word is the SAO satellite number, convert to SPADATS number by using Satellite table. Syncom II 63311 is object number 634, and is logged in cc 1-3.
2. Each observation consists of 4 lines. The station name is the first word of each line. Convert to SPADATS sensor number, and log in cc 6-9. The second word of each line is date of observation, and is logged in

cc 11-15. Time is word three and four of each line. Use only line one, the average observation time, and log in cc 16-24. The fifth word is the observation type code (1 digit). See figure 5.3.

a. Type code 5 indicates elevation in degrees and tenths of degree (3 digits). Log in cc 25-27 adding 0 in cc 28-30.

b. Type code 1 indicates slant range in meters (9 digits). The decimal point falls after 6th digit. Insure decimal point is in the correct place on log sheet. Log in cc 38-44. The last digit is rounded off.

c. Type code 9 indicates range rate, and is logged in cc 45-51 adding 0 in 52-53. Minus sign as indicated on message is logged in cc 45. If no minus sign is indicated, plus is understood and a 0 is logged in cc 45. The decimal point falls after the first digit.

d. Type code 4 indicates azimuth in degrees and tenth of degree, and is logged in cc 31-34 adding 0 in cc 35-37.

3. Type 25 is logged in cc 4-5, accuracy of observation is 0 and is logged in cc 10.

4. Classification (U or C) as indicated by message is logged in cc 71.

Figure 5.3

Observation Type Codes As:

1 - Range in meters (9 digits).

4 - Azimuth in degrees and tenths of degree (4 digits).

5 - Elevation in degrees and tenths of degree (3 digits).

9 - Range Rate in meters per/second.
Given to nearest .01 meters per/second (sign and 6 digits).

5.3.11 681/682 Format

5.3.11.1 Example

```
$$$$$
tSTAa    OBJEC    YMoDa
HHMMSS   Q    DDDdd    DDdd    XXXXXXXX
)))))
```

Line	Code	Meaning
1	$$$$$	Conninctimg Call Code
2	t	Observation type
	STA	SPADATS Sensor #
	a	Observation accuracy
	OBJEC	SPADATS Object #
	YMoDa	Date of Observation
3	HHMMSS	Time of Observation
	Q	Data Quality
	DDDdd	Azimuth
	DDdd	Elevation
	XXXXXXXX	Frequency
4	)))))	Disconnect Call Code

5.3.11.2 Handlogging Procedures

1. First word of line one is connecting call code and is unused in hand-logging.
2. Second line:
   a. Type, first digit, of line two is observation type. 681/682 is type 32, and is logged in cc 4-5. The next three digits are SPADATS sensor number. Log in cc 7-9 with a 0 in cc 6. Last digit of word one is accuracy of observation, and is logged in cc 10.
   b. Second word is SPADATS object number. Log last three digits in cc 1-3.
   c. Third word, date of observation, is logged in cc 11-15.

3. Third line:

   a. Time of observation, first word, is logged in cc 16-21 adding 0 in cc 22-24.

   b. Data Quality, second word, 7 - Best, 4 - Good, 0 - Poor, is for analyst use only.

   c. Azimuth, the third word, is in degrees and hundreth of degrees. Log in cc 31-36 adding 0 in 37-38.

   d. Elevation, the fourth word, is in degrees and hundredth of degrees. Log in cc 25-28 adding 0 in cc 29-30.

   e. Last word is not used in handlogging.

4. If no header card is on the message, log information for cc 1-15 from text of message. Station 1 is 681 and Station 2 is 682. If text of message is omitted, message DE line will be FTMEAD. The DSSO will advise you on necessary information for Object number, Station number, and date.

5. The classification as indicated on message is logged in cc 71.

e. Slant range is in kilometers and is logged in 39-42 preceded by a 0 in cc 38. Decimal point is understood at the end of the field. Add 0 in cc 43-44.

f. Log digits for range rate in cc 46-50, adding 0 in cc 51-53. Log 0 in cc 45. If a minus sign precedes the field, an eleven overpunch is needed in cc 45.

g. Classification (U or C) as indicated on messages is logged in cc 71.

e. Slant range is in kilometers and is logged in 39-42 preceded by a 0 in cc 38. Decimal point is understood at the end of the field. Add 0 in cc 43-44.

f. Log digits for range rate in cc 46-50, adding 0 in cc 51-53. Log 0 in cc 45. If a minus sign precedes the field, an eleven overpunch is needed in cc 45.

g. Classification (U or C) as indicated on messages is logged in cc 71.

5.3.13 Code Tables

5.3.13.1 Observation Accuracy Code*

VISUAL OBSERVATIONS: Equipment Code 01 through 20	CODED	ELECTRONICS OBSERVATIONS: Equipment Code 21 through 53
Normal Observation made under fail conditions	0	Signal strength good, reliable measurements.
Observation slightly under par due to outside interference (e.g., some clouds, reduced visibility)	1	Signal strength fail.
Observation poor due to outside interference.	2	Signal weak, results poor.
Only estimate possible (Malfunction of equipment, too short time of object seeing).	3	Signal questionable.
Doubtful observation, unable to verify either object of instrument behavior. Observation should be considered only as tentative.	4	

* Column 10 of Satellite Observation Conversion Sheet

5.3.13.2 Instrument Code

01 Visual observation without instruments. Estimates of h, z, or α. δ only.
02 Visual observation with binoculars or small telescopes. Estimate only.
03 Optical observation with wide circles (Accuracy not better than ± 1/2 Degree).
04 Same as 03, accuracy ± 1/2 to 1/10 Degree.
05 Same as 03, accuracy better than ± 1/2 Degree & Time better than 1/5 Second.
06 Same as 03, accuracy better than 1 Minute of Arc, and Time to 1/100 Second.
07 Special code for observations with instruments specifically designed for tracking.
11 Photographic observations with very short-ratio and small frame (e.g., 35 MM Lecia etc.); positions obtained by simple linear interpolation in starfield.
12 Same as 11, but carefully analyzed (measured/positions).
13 Photographic observations with larger telescope and/or larger place (e.g., Astrograph, Schmidt telescope, ROTI, etc.).
14 Same as 13, but carefully measured and reduced.
15 Photographic observations with special tracking camera (ballistic camera, phothead) carefully analyzed or QUICK LOOK DATA for codes 11 or 13.
16 Photographic observations with BAKER-NUNN Cameras, direct data readout no special reduction (preliminary data).
17 Same as 16, final analysis with all corrections made.
21 Radar observations with fixed beam antenna.
22 Radar observation with moving beam, no self-tracking feature. Data readout from position of dials.
23 Radar observation with moving beam antenna "T" tracking capability. Data readout by dials.
24 Same as 22, data readout automatic.
25 Same as 23, data readout automatic.
31 Passive tracking data from telemetry systems (e.g., TLM-18). Disk with diameter of less than 20 feet. Angular data accuracy not better than 1 degree.
32 Same as 31, disk diameter between 20 and 59 feet.
33 Same as 31, disk diameter over 60 feet.
34 Same as 31.
35 Same as 32 with angular accuracy better than ± 1 Degree.
36 Same as 33 ± 1/10 Degree.
37 Same as 31.
38 Same as 32 but angular data accuracy better than ± 1/10 Degree.
39 Same as 33.
41 Doppler observations (passive track). Signal strength accuracy see section 5.3.13.1
42 Direction finding system. Signal strength accuracy
43 Interferometer system. Signal strength accuracy
51 Fence observation (Minitrack).
52 Fence observation (Microloc).
53 Fence observation (Doploc).

5.3.13.3 Time Accuracy Code

0 = At the full second (next 2 digits must be zeros).

1 = At the 1/10 second (last digit must be zero).

2 = At the 1/100 second (last digit).

5 = At the ten second digit (accuracy ± 5 second: second digit can be 0 to 9).

9 = At the minute (any seconds will be considered estimates only).

5.3.13.4 Time Zone Code

0 = ZULU (Z)

4 = Eastern Daylight (EDT)

5 = Eastern Standard (EST)
Central Daylight (CDT)

6 = Central Standard (CST)
Mountain Daylight (MDT)

7 = Mountain Standard (MST)
Pacific Daylight (PDT)

8 = Pacific Standard (PST)

5.4 GLOSSARY OF ABBREVIATIONS

COSPAR	- Committee on Space Research, an international space agency established by the International Council of Scientific Unions.
CPA	- Closest Point of Approach.
DC	- Differential Correction.
DIA	- Defense Intelligence Agency.
DIP	- Display Information Processor. The computer used to generate the BMEWS displays in the NORAD COC.
DMNI	- Device for multiplexing non-synchronous inputs.
DMNO	- Device for multiplexing non-synchronous outputs.
DOM	- Day of month.
DOY	- Day of year.
EFTO	- Encrypted for transmission only.
ER	- Earth radii, as a unit of distance. Also earth's rotation.
IGY	- International Geophysical Year.
MJD	- Modified Julian Day.
N-M Element Set	- An element set based on vectors. N is a geocentric unit vector directed toward the ascending node. M is a vector directed toward and in the same plane as the orbit path and normal to N.
OCS	- Orbit Computation Sequences.
Q-Points	- The effective fix on an object which results from scan-to-scan comparative analysis in a fan from either detection radar or tracking radar at the BMEWS sites.
RA	- Right ascension.
RMS	- Root mean square.

RPL	- Running Program Language.
SAO	- Smithsonian Astrophysical Observatory.
SATEV	- A code that defines the particular format in which observations from COSPAR stations are received.
SATOF	- A code that defines the particular format in which observations from COSPAR stations are received.
SATOR	- Satellite orbits.
SATTB	- Satellite table, containing satellite numbers automatically selected by the RASSN Program for further processing.
SATUG	- A code that defines the particular format in which observations from COSPAR stations are received.
SEAIC	- Sensor, Element, Acquisition, Information and Communications files.
SRADU	- A B-2 tape file containing Sorted Reports, Associated, Doubtfully Associated, Unassociated.
STC	- Sunnyvale Test Center, Sunnyvale, California.
SSO	- Special Security Officer, Air Force Security Service Network.
SYNCOM	- Defines code format in which observations are received from this satellite source.
SYS	- The Philco Utility Program System.

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